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Evaluating Emergency Management Models and Data Bases: A Suggested Approach

Robert E. Chapman, Saul I. Gass and James J. Filliben

U.S. DEPARTMENT OF COMMERCE
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(Formerly National Bureau of Standards)
Center for Computing and Applied Mathematics
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March 1989

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National Bureau of Standards became the National Institute of Standards and Technology on August 23, 1988, when the Omnibus Trade and Competitiveness Act was signed. NIST retains all NBS functions. Its new programs will encourage improved use of technology by U.S. industry.

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A NOTE TO THE READER

On August 23, 1988, the Omnibus Trade and Competitiveness Act (Public Law 100-418) was signed into law. The Act created the National Institute of Standards and Technology (NIST) from the National Bureau of Standards (NBS). Since 1901, NBS has served as the Nation's central laboratory for developing and disseminating measurement standards and scientific data.

Central to the competitiveness portion of the Act was the expanded mission of NIST. The Institute's new responsibilities augment and build on the technical expertise of NBS, the only Federal laboratory with a specific mission to support U.S. industry.

NIST will maintain the traditional functions of NBS and will continue to offer the full array of measurement and quality assurance services that were provided by NBS. These services include calibration services, standard reference materials, standard reference data, and measurement assurance programs.

PREFACE

The Center for Computing and Applied Mathematics, National Engineering Laboratory, National Institute of Standards and Technology (NIST) is conducting a research effort under the sponsorship of the Federal Emergency Management Agency (FEMA) to develop a set of guidelines which promotes both a critical review and unbiased evaluation of FEMA models and data bases.

Large-scale models and data bases are key informational resources for FEMA. The type and nature of FEMA models and data bases, however, are perhaps unique within the Federal government in that they are often concerned with severe changes or disruptions ranging from limited effects to extremes. In order to carry out its emergency missions, it is necessary for FEMA to determine which models, modeling techniques and data bases are appropriate for what purposes and which ones need modification, updating and maintenance. The development of evaluation guidelines is therefore of direct benefit to FEMA in discharging its emergency management duties.

FEMA's Dynamic General Equilibrium Model (DGEM) was subjected to a critical review and evaluation of its capabilities as a military mobilization model to test and illustrate the approach recommended for evaluating emergency management models and data bases. DGEM is ideally suited for this purpose because it was designed to deal with economic and policy impacts of energy and resource supply (disruptions), catastrophic losses of resources and recovery from enemy attack, and demand and production surges and resource constraints during a military mobilization. It is hoped that these evaluation guidelines and their application to DGEM will prove useful to emergency managers and decision makers both in the application of these guidelines to other emergency management models and data bases and in their understanding and appreciation of the capabilities provided in DGEM.

EXECUTIVE SUMMARY

The purpose of this report is twofold. First, it is designed to provide the reader with a generic set of guidelines which can be used to evaluate large-scale, computer-based models and data bases. Second, the guidelines are illustrated through a critical evaluation of the Dynamic General Equilibrium Model (DGEM). DGEM is currently being used by the Federal Emergency Management Agency (FEMA) to analyze a variety of emergency management problems. The evaluation of DGEM serves both as a step-by-step procedure for conducting an in-depth model evaluation and as an introduction to a non-proprietary model which has broad applicability to the analysis of macroecomic issues.

Many of the models currently in use within government and the private sector are by definition complex and large-scale. Consequently, the ability to produce accurate and realistic estimates of alternative courses of action has become a most challenging task. Furthermore, many models are dependent on data bases that are generated and maintained by diverse organizations, with each data base having a raison d'etre that may or may not be relevant to the problem under review. It should then be clear that the acceptance of model outputs as inputs to the decision-making process without investigating the validity of their generation is a luxary that the community of model users can no longer afford.

Over the past 15 years a body of research has been developed that addresses the concern of model users who, upon being presented with the results of a computer-based model analysis, must decide whether the results are accurate enough or appropriate for the problem under review. This research - termed model evaluation - has contributed greatly to our ability to understand better the role of modeling in policy-oriented decision making.

Model evaluation may take on a variety of forms and levels of complexity. However, any evaluation procedure has at least the following essential phases:

1. Obtain a clear and comprehensive statement of user requirements and objectives pertaining to the application of the model;

2. Generate appropriate information about the model design and performance pertaining to user requirements; and

3. Evaluate model attributes and properties according to predetermined criteria of performance required by the user.

These phases are characterized by the following activities:

° Determine user requirements and objectives.

° Based on user requirements, develop questions to be answered about model performance and identify problems to be resolved or analyses to be performed.

- Ascertain from the questions any problems for which specialized techniques are to be used to generate information needed about model design or performance relevant to the intended application of the model by the user.

- Perform the necessary tasks to generate the needed information for the evaluation.

- Establish criteria for the model evaluation.

- Conduct a formal evaluation to judge the integrity of the model relative to its intended use.

The first five chapters of this report focus on the development of a generic evaluation procedure. Additional material on the general topic of model evaluation is presented in Appendices A, B and C. The remainder of the report illustrates how the procedure was applied to DGEM.

DGEM was selected for evaluation primarily for its unique approach to modeling emergency situations. The availability of documentation was also a major factor. We wish to alert the reader to the importance of documentation in any model evaluation effort because it is a means through which performance against user requirements can be measured.

From a review of the DGEM documentation, it became clear that much care went into the design, development and testing of the model. Furthermore, the model's documentation is quite complete and should be sufficient to: (1) set it up on the host system; (2) execute a base-case simulation; (3) interpret the results of the base-case simulation; and (4) create, run, and interpret user-specified simulations.

The analysis of the U.S. economy during a military mobilization is used to illustrate the generic evaluation procedure. This approach was taken for two reasons. First, a military mobilization represents a major perturbation about DGEM's "business as usual" base-case simulation. Consequently, any weaknesses of the model (e.g., instabilities, implausible results, etc.) should be revealed by such a perturbation. Second, a military mobilization requires an explicit treatment of the joint interactions of several factors (e.g., international trade, the business cycle, available capacity, investment, etc.).

The formulation of the mobilization scenario used in the evaluation of DGEM was a two-stage process. In the first, a mobilization baseline was constructed which made explicit the perturbation about the business as usual values in the DGEM data base. The mobilization baseline also provided a point of reference for how the joint interactions of the perturbation affected the path of the national economy. In the second, six key variables were varied in combination subject to an experimental design. This enabled us to explore in detail cetain patterns which were uncovered in the mobilization baseline.

For the case at hand, DGEM was found to produce solutions which were both realistic and internally consistent from an economic perspective. This is especially important in light of the results of the structured sensitivity analysis because the model was sufficiently robust to produce meaningful estimtaes of key economic variables even though many of the "input" variables were significantly different from their business as usual values. Finally, DGEM's analytical approach and detailed reporting format enabled us to illustrate how techniques used in a model evaluation can be applied to major studies with policy implications.

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Drs. Edward A. Hudson and Richard J. Goettle of Dale Jorgenson and Associates deserve special praise for their cooperation in the evaluation of the Dynamic General Equilibrium Model (DGEM). As model developers and principal architects of the current version of DGEM, they exhibited the highest standards of professionalism during the entire period of review, modification, and evaluation of their model. Their cooperation proved that model evaluation can be a two-way street in which all parties, especially the user community, benefit. Prof. Ernst R. Berndt of MIT provided many valuable insights. His view of model evaluation was particularly useful in establishing some of the user requirements given in Chapter 6.

Messrs. E. Lawrence Salkin and O. Cleveland Laird of FEMA and David K. Henry and Albert Walderhaug of the Department of Commerce lent their skill and experience in modeling military mobilizations to the project. The many discussions with these individuals were crucial to the formulation of the military mobilization presented in Chapter 9 which was used to evaluate DGEM and, at the same time, illustrate the guidelines described in Part I of this report.

Special appreciation is extended to Mr. A. Jeffrey Shibe of the Center for Fire Research at the National Institute of Standards and Technology for his critical review of this report. His comments enabled us to both simplify and clarify the presentation of several key points. We also wish to acknowledge the assistance provided by our colleagues, especially Dr. Javier Bernal and Mr. Robert G. Hendrickson. Dr. Bernal played a major role in the conversion of DGEM from a machine-dependent version of FORTRAN to the current version which complies with the ANSI X3.9-1978 standard. Mr. Hendrickson's involvement during the early stages of this project was helpful in establishing the evaluation guidelines described in Part I of this report.

1. INTRODUCTION

1.1 BACKGROUND

The subject of model and data base evaluation has grown rapidly in importance during the last 15 years. This trend is due primarily to a shift in the type of models being developed by members of the operations research and management science communities. During the period immediately following World War II, numerous large-scale models were developed and used by management as aids to decision making. In many cases these models dealt with production-oriented problems. Model evaluation was thus fairly straightforward, in that a recommended solution could be implemented and the response measured against predictions. However, as one moves from engineering-based, production-oriented problems to the realm of policy analysis, the problem becomes more complex. No decision maker faced with implementing a major policy is in a position to control all of the variables to attain the desired response. Consequently, to compensate for this situation, the types of models used to provide information to decision makers have become both large and complex. Although many traditional mathematical tools are used in such models to make the analysis tractable, the implications of their use must be carefully stated if the model's results are to be useful, usable and used by the decision maker.

The problems associated with the use of large-scale models in the policy arena have led a number of researchers to advocate the development of well-defined sets of model and data base evaluation guidelines. One of the best known positions, advocated by Saul I. Gass,[1] stresses the role of evaluation as an integral part of the building and use of any large-scale, policy-oriented model. Gass provides three reasons for advocating this form of evaluation:

(1) in many cases, the ultimate decision maker is far removed from the modeling process and needs a basis for deciding when to accept the model's results;

(2) users of a model developed for others must be able to obtain a clear statement of the applicability of the model to their problem area; and

(3) it is difficult to assess the impact of a model's assumptions, data availability, and other elements on the model's structure and results without a formal, independent evaluation.[2]

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[1]Gass, S.I. "Decision-Aiding Models, Validation, Assessment, and Related Issues for Policy Analysis," Operations Research, Vol. 31, No. 4, 1983, pp. 603-631.

[2]It is important to recognize that model evaluation is not model certification. Certification commonly refers to a guarantee that the model yields outputs and results that are suitably accurate for a particular application. This is an unattainable goal for the policy-oriented models that are of concern here. Evaluation, on the other hand, acknowledges this limitation, and seeks to improve the model's usefulness by identifying as explicitly as possible, its strengths, weaknesses, and appropriate uses.

Since this report focuses on the subject of model and data base evaluation, it is first useful to introduce and define a few key terms. The literature on model and data base evaluation refers to the following key procedures: (1) documentation; (2) verification; and (3) validation. Since many authors are writing on this subject area,[1] there is often disagreement on the exact definition of each term. A definition of each term is therefore given here in order to promote an understanding of the topics which follow.

Documentation refers to the written description of the model. In practice a variety of reports comprise the documentation for the model. These reports include such information as:

(1) precise statements of what the model is supposed to do;

(2) the mathematical/logical definitions, assumptions, and formulation of the problem; and

(3) a complete set of operating instructions for the user, including current inputs, outputs, test cases, options and limitations.

Among the major purposes of documentation are: (1) to promote the intelligent use of the model; (2) to provide a technical knowledge base; and (3) to broaden the class of users. Although documentation is not designed for model evaluation *per se*, it is the cornerstone of any evaluation effort. Without documentation a model can, at best, be considered a black box.

In most cases the documentation describes what the model should do; but may not necessarily describe what it really does. The truth of the previous statement rests on the recognition that the documentation describes both the abstract model and the operational model. Since the operational model is embodied in a set of computer code, referred to hereafter as the program, the relationship described in the documentation may be imperfect. It is therefore necessary to ensure that the program:

(1) describes accurately the model as designed;

(2) is properly mechanized on the computer; and

(3) runs as intended.

The process of documenting the relationship between the abstract and operational model is referred to as verification.

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[1]For a review of the literature on model and data base evaluation see: Chapman, R.E., R.G. Hendrickson and S.F. Weber. A Survey of Techniques for Evaluating Emergency Planning Models and Data Bases. Gaithersburg, MD: National Bureau of Standards, NBSIR 84-2963, 1984.

The third term, validation, refers to the correspondence between the outputs of the model and the real-world situation it was designed to simulate. Given the complex nature of policy-oriented problems it is useful to differentiate between two forms of validation. The first, objective validation, is primarily concerned with model-subject fidelity and the degree to which the model represents reality. The second, subjective validation, is based on the intended use of the model and the extent to which the model satisfies the needs of the user. For cases in which models are used to assess the consequences of alternative policies, an objective validation is usually impossible. This is because constraints on available data and computer resources may require substantial simplification of the model design, so that the model focuses only on certain aspects of the situation which are of crucial importance to the decision maker. When this view is taken, the relevance of subjective validation to the policy arena becomes evident.

1.2 PURPOSE

The purpose of this document is twofold. First, it describes four major classes of analytical techniques which are capable of addressing the quantitative issues of model and data base evaluation. These techniques are designed to generate information which can be used to test the degree to which a particular model or data base satisfies a specific set of user requirements. Second, this document focuses on how user requirements are determined and how a test against these requirements is performed. This approach is taken to illustrate how the four classes of analytical techniques provide the information required to perform an in-depth evaluation.

1.3 SCOPE AND APPROACH

Model evaluation may take a variety of forms and levels of complexity. Irrespective of the form and level, however, a thorough evaluation procedure is based on three essential phases:

(1) obtaining a clear and comprehensive statement of user requirements and objectives pertaining to the application of the model;

(2) generating appropriate information about the model design and performance pertaining to user requirements; and

(3) evaluating model attributes and properties according to predetermined criteria of performance required by the user.

The last phase includes an assessment of the model's qualifications as a tool in the desired policy analysis. These three phases may be formally characterized by the following activities:

(1) determine user requirements and objectives;

(2) based on the statement of user requirements, develop questions to be answered about model performance and identify problems to be resolved or analyses to be performed;

(3) ascertain from the questions any problems for which analytical techniques are to be used to generate information needed about model design or performance relevant to the intended application of the model by the user;

(4) perform the necessary tasks to generate the needed information for the evaluation;

(5) establish criteria for the model evaluation; and

(6) conduct a formal evaluation to judge the integrity of the model relative to its intended use.

These activities emphasize the importance of a thorough and comprehensive statement of user requirements to the process and to the success or failure of the evaluation. The way in which these activities are integrated into an evaluation procedure is summarized in Figure 1.1. It is important to note that the three major components (user requirements, information development and generation, and evaluation of test results) shown in Figure 1.1, comprise a framework for the NBS model/data base evaluation guidelines.

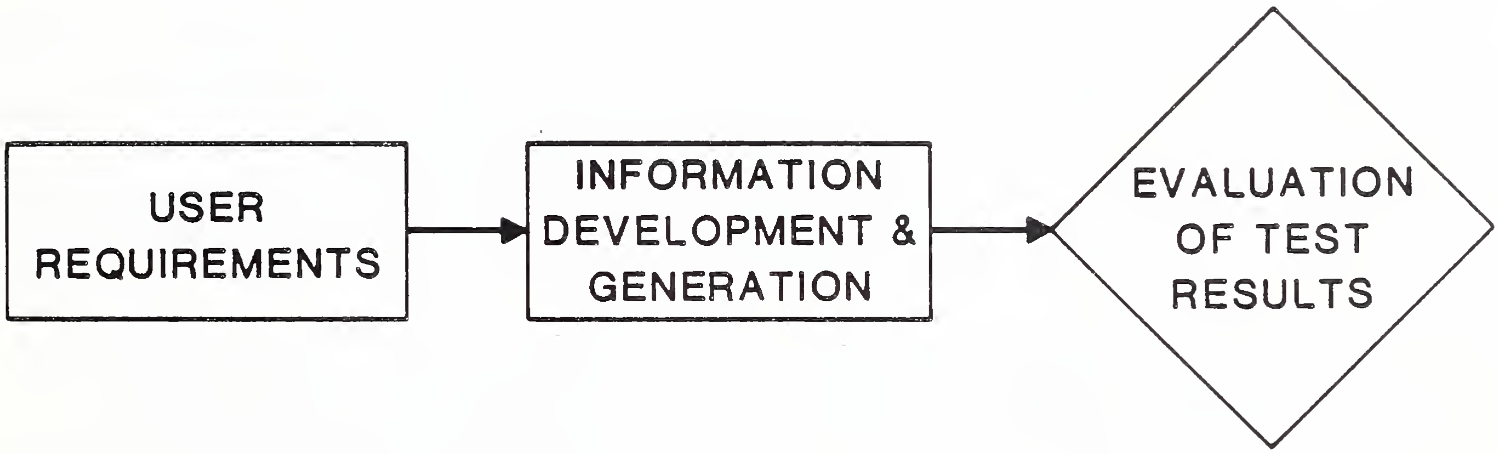
This report focuses on the central role played by a comprehensive set of analytical techniques in the development and generation component of the evaluation procedure which appears at the center of Figure 1.1. Specific analytical techniques are described in Part I, Chapters 2 through 5. Part II, Chapters 6 through 10, serves to relate these techniques to the framework of structural information and analysis which supports an in-depth model/data base evaluation.

Chapter 2, Descriptive Analysis, focuses on the development and organization of background information about the model, which includes the motivation for the model creation, its design and theory, and the conditions under which it was developed. The chapter also develops a framework through which the real world problem may be related to the conceptual model used to formulate the mathematical model and the resulting operational model.

Chapter 3, Program Verification and Analysis, treats the importance of the clarity, completeness, and adequacy of the model's documentation. The details are realized from three activities: (1) an in-depth review of documentation format, structure, and content; (2) a review of the source code; and (3) an assessment of experiences in using the model.

Chapter 4, Data Audit, discusses the evaluation requirements as they pertain to: (1) review and clarification of data definitions; (2) analysis of the nature and structure of the data base; (3) analysis of the file computerization and accessibility; (4) determination of data sources; and (5) analysis of the quality of selected, important data by estimating uncertainties formulated as bounds on the data variability.

Figure 1.1 A Suggested Approach for Evaluating Emergency Management Models and Data Bases



Chapter 5, Sensitivity Analysis, describes the role of sensitivity analysis in model evaluation and its contribution to quantitative and qualitative information development relevant to the needs of the model assessment process.

Chapter 6 establishes a set of four user requirements which provide the means for evaluating DGEM. Requirement 1 focuses on model usage (i.e., the operational model). Requirement 2 addresses the clarity and completeness of the documentation for the conceptual and mathematical models. Requirement 3 focuses on the relationships between the National Income and Product Accounts (NIPA) and the model's output. Requirement 4 is concerned with a variety of economic-technical attributes.

Chapter 7 addresses the issues raised in Chapters 2 and 3. Background informatin, which serves to define the motivation for the model and its theoretical under pinnings, is presented first. The focus is then shifted to the DGEM software, including: (1) a review of the DGEM source code; (2) the implementation of the model on the NBS computer system; (3) enhancements which were made to the basic code; and (4) a report on the evaluator's hands-on experiences.

Chapter 8 focuses on an audit of the DGEM data base. Material is presented which documents the extensive testing that was performed on the DGEM data base by its developers (e.g., comparisons with realized values, assumptions involved in projections up through the year 2000, etc.) as well as independent studies (e.g., concerns about substitution elasticity estimates, the treatment of capital aggregation, etc.).

Chapter 9 provides information on the mobilization scenario used in the evaluation of DGEM. The mobilization scenario analyzed with DGEM is patterned after an unclassified scenario approved by DoD. Basically, the scenario indicates a conventional war of three years duration in Europe, the Persian Gulf and Korea. The period of the mobilization follows that of the unclassified DoD scenario and is assumed to be 1983 through 1986. The first year represents a period of buildup prior to the onset of hostilities. For each year of the mobilization, values for key economic variables were specified. Once the "mobilization baseline" had been established, a structured sensitivity analysis was performed.

Chapter 10 provides a summary of major findings. Material is presented which compares critically information generated in the model evaluation process against user requirements. This comparison enables us to conclude that DGEM is both an appropriate and useful model for analyzing the types of problems anticipated during a military mobilization.

1.4 A PRIMER ON EMERGENCY MANAGEMENT: PROBLEMS, POLICIES AND MODELS

The ability of public officials to respond correctly to an emergency situation is conditioned by their being able to recognize that a particular type of emergency has occurred, and to initiate predetermined and ad hoc actions designed to alleviate the situation. Some localities have established contingency plans in the area of public safety. Many metropolitan areas, and local councils of governments, have centralized the process by which an emergency is declared and resources positioned for action and response (e.g., during a hurricane or blizzard). Some localities have functioning command centers that enable them to pool, coordinate and allocate emergency resources. In general, however, the management of the response to an emergency tends to be reactive instead of proactive. Other aspects of emergency response are: (1) the need to determine appropriate guidelines for response actions and allocations of resources under changing conditions; (2) the training of emergency managers; and (3) the development of computer-based decision aids for use by emergency managers.

From a national perspective, the Federal Emergency Management Agency (FEMA) has an important and direct role in ensuring that our citizens and their property are given the best protection under all emergencies. FEMA's major activity areas center around four policy issues. The first, mitigation, consists of those activities which eliminate or reduce the probability of occurrence of an emergency. It also includes long-term activities which reduce the effects of unavoidable emergencies. The second, preparedness, involves activities by governments, organizations and individuals to develop plans to save lives and minimize damage. Preparedness measures also seek to enhance response operations. The third, response, includes activities to provide warning, population protection, and emergency assistance. They also seek to reduce the probability of secondary damage and to speed recovery operations. The fourth, recovery, consists of both short-term and long-term activities. Short-term recovery returns vital life-support systems to minimum operating standards. Long-term recovery may continue for a number of years after a disaster. Their purpose is to return life to normal, or improved levels.

Associated with each policy issue is a series of general measures which cut across all emergencies and a series of emergency-specific measures. The general measures associated with each policy issue are summarized in Table 1.1.

Emergencies may be classified according to type and size. The types of emergencies include: (1) natural disasters; (2) technological emergencies; (3) resource shortages; (4) disorders; and (5) war. The various types of emergencies can be ranked by magnitude into local, regional, national, and international emergencies. It should be recognized, however, that there are variations in individual emergencies and that local emergencies may be of national or international interest and/or impact.

A framework for mobilizing the resources which may be needed is outlined in National Security Decision Directive 47 and Executive Order 11490 in order to address the types of emergencies just mentioned. Seven categories serve to define the context of emergency mobilization. These categories are described in Table 1.2.

National Security Decision Directive 47 states that it is the policy of the United States to have an emergency mobilization capability that will ensure that government, at all levels, in partnership with the private sector and the American people, can respond decisively and effectively to any major national emergency.

Executive Order 11490, Assignment of Emergency Preparedness Functions to Federal Departments and Agencies, requires departments and agencies to prepare national plans and programs and to attain an appropriate level of readiness with regard to the functions assigned. It also requires the Director of FEMA to establish Federal policies for and coordinate all emergency preparedness activities and functions of the Federal Government, and be responsible for the preparation of guidance to Federal departments and agencies to assist them in performing their assigned emergency functions.

The final consideration in emergency mobilization preparedness is the timing of management actions. Four phases have been established for planning purposes. In a real emergency the phases may not exist in clearly discernible stages, but they do provide a useful framework for planning for the full range of management actions. The relationship between the policy issues, the scale of the emergency and the time frame is illustrated in Figure 1.2.

There exists a diversity of activities and related problems that FEMA must address in carrying out its mission. FEMA's activities include day-to-day data gathering, responding to the immediate needs of an emergency, and strategic planning and analysis. It is not our purpose to be complete here, but instead to emphasize the decision making requirements faced by FEMA and related organizations and individuals.

Central to all of FEMA's activities is a viable and current information support system that is directed toward the needs of emergency managers. Such a system is defined to include not only data and descriptive information, but also analysis and interpretive programs. The establishment and maintenance of this support system, although a problem in itself, cannot be accomplished without recognition of the decision problems and other related problems of emergency managers. These include the development and implementation of training procedures for emergency managers at all levels, the requirement of emergency managers at all levels to be able to find and interpret current emergency response rules and regulations, the need of FEMA to be able to evaluate proposed emergency guidelines and legislation, and the basic management procedural requirements for coordinating multi-regional responses and allocations of resources. Thus, to be effective, an information support system must be designed to reflect the needs of these varied problems. In particular, one must be cognizant of the many confounding and limiting aspects inherent in the broad spectrum of emergency operations. These include the varied nature of emergencies and the extremely wide range of possible responses requiring formal evaluation procedures.

The time taken to respond to an emergency can also be critical. Public safety organizations (e.g., police, fire, ambulance service) are always on duty and take pride in their short response times. But for broader emergency situations, like toxic and explosive spills or hurricanes that require decision structures and response systems that are basically dormant, the ability to mount a proper and timely response is difficult. Here, emergency managers must be able to couple their static personnel and resource base with sporadic incoming information to make a dynamic set of responses. This can

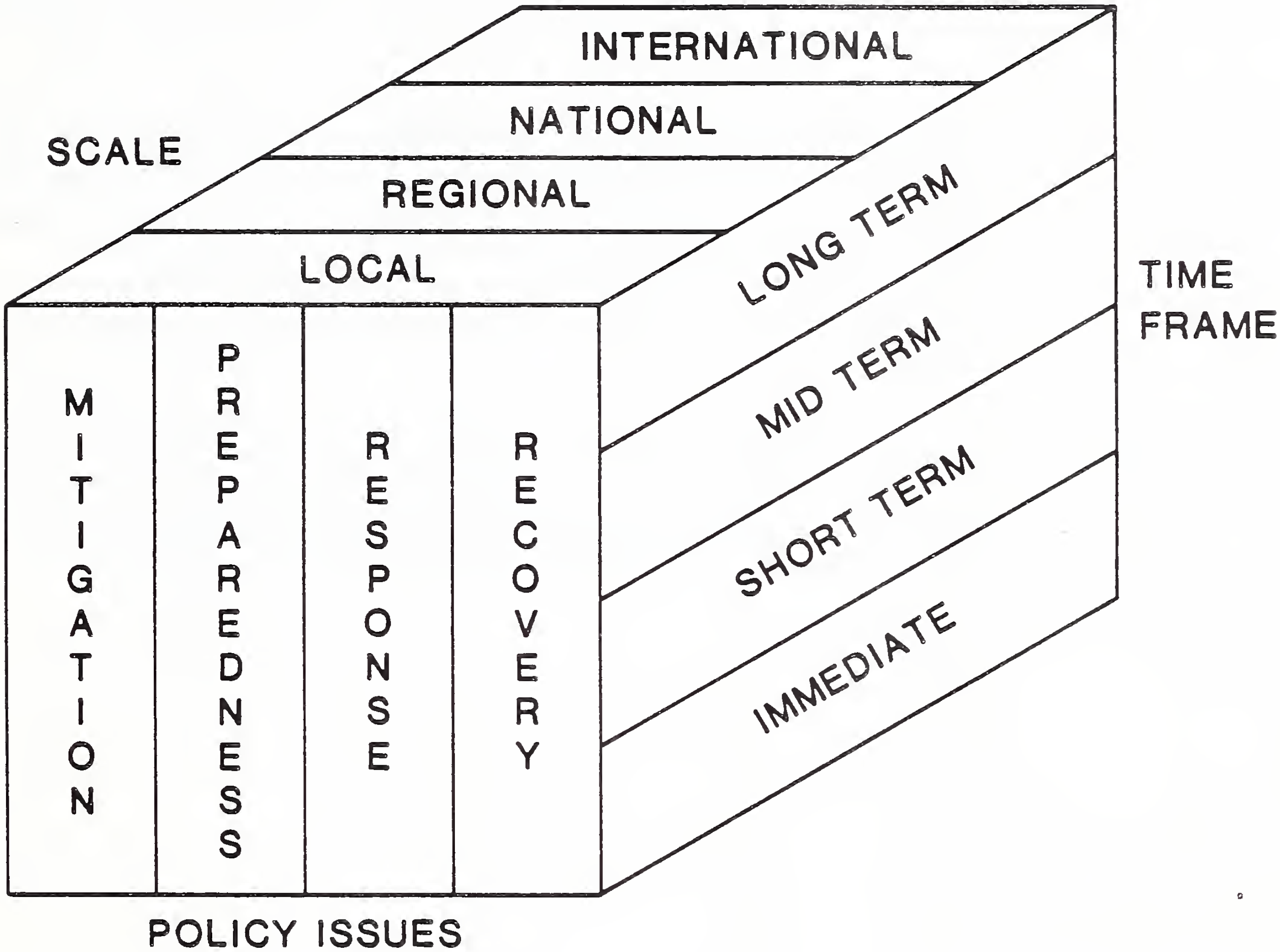
Table 1.1 General Measures Used as a Function of th Policy Issue

Issue	Measure
Mitigation	Building codes Zoning and land use management Compliance and enforcement Public education
Preparedness	Preparedness plans Emergency exercises/training Emergency communications systems Evacuation plans and training
Response	Activate public warning Mobilize emergency personnel/equipment Emergency medical assistance Man emergency operations centers
Recovery	Damage insurance/loans and grants Temporary housing Disaster unemployment insurance Economic impact studies

Table 1.2 Mobilization Categories

Category	Definition
Military Mobilization	The act of preparing for war or other emergencies through assembling and organizing military resources.
Industrial Mobilization	The process of marshalling the industrial sector to produce goods and services required to support military operations and the needs of the civil sector during domestic or national security emergencies.
Economic Mobilization	The process of marshalling the money, credit, and taxes needed: (1) to finance the management of the emergency; (2) to maintain a stable economy; and (3) to stimulate key sectors of the economy.
Infrastructure Mobilization	The process of marshalling the output of infrastructure systems to support the entire mobilization.
Human Resources Mobilization	The process of marshalling people to provide needed labor.
Government Mobilization	The process of marshalling resources of Federal, State and local governments to carry out the tasks required to manage emergencies
Civil Preparedness Mobilization	The process of marshalling resources to provide protection for the people, industry, and institutions of the United States against the effects of the spectrum of emergencies.

Figure 1.2 Conceptual Framework for Emergency Mobilization Preparedness



only be effective if a full range of contingency plans has been developed and tested by the emergency management team. Such contingency planning is not a priority item at most levels of emergency management. It is costly, it requires experienced personnel, but it is a tactical activity that must be placed on a solid base.

The analysis of emergencies and emergency responses is backed up with some theory on the physics of particular emergencies, but little theory on the behavioral aspects of most emergencies. There are fire spread models, nuclear blast and fallout models, network flow models, epidemiological models, some of which can be of assistance in contingency planning, as well as in an operational situation. A key question is how available theory can be utilized in an emergency information support system, especially at the local level.

One is quick to recognize that the major concerns of emergency management operations, like all complex decision situations, have both technological and human components. And, as the problem is of national importance and something must be done to understand better all aspects of emergency management, there is a danger of rushing to apply technical methodologies. An integrated emergency information-communications system will be ineffective if the personnel and behavioral aspects of who is to use it, how will the users be trained, and what the decision and resource needs of the users are ignored.

From a general emergency perspective, the individuals, and groups that concern themselves with an emergency (i.e., the stakeholders and actors) include persons at the Federal, State and local levels, as well as persons in private sector organizations. Thus, emergency management operations and supporting systems must be responsive to a wide diversity of needs and priorities.

PART I

GUIDELINES FOR EVALUATING EMERGENCY MANAGEMENT MODELS AND DATA BASES

2. DESCRIPTIVE ANALYSIS

A descriptive analysis focuses on providing background information on the model. Such information includes the motivation for the model, its organization and theoretical underpinnings, and the conditions under which it was developed.

As a first step, the descriptive analysis should document the policy context and the real world conditions for which predictions are desired. This information should provide a background for evaluating the appropriateness and relevancy of the model. Information on the model's organization promotes a more thorough understanding of the model's structure, its inputs and outputs and general flow of information. A major component of the descriptive analysis is a review and summary of key publications describing the model's objectives, structure and principal results. The literature review is also helpful in evaluating the appropriateness of the model's structure for dealing with policy issues and the plausibility of its results. Finally, it is useful to know the conditions under which the model was developed. This information is intended to alert the users or evaluators to special circumstances of development likely to make the model either more or less suitable for the proposed application.

2.1 MOTIVATION FOR THE MODEL

This portion of the evaluation consists of four components. The first component focuses on a description of what is to be described by the model and why. The second discusses how to apply the model to the problem(s) of interest. The third describes how the various parts of the model fit together. The final component provides a means for documenting which, if any, previous models may have influenced the development of the current model.

To facilitate the discussion which follows, we may note that there is a real world problem which is of interest. This problem provides the motivation for model development, because a model provides a method of analysis. However, in order to develop a model, it is necessary to make certain assumptions and simplifications. These notions may be quite general and hence serve only as an outline of how to build the model; they may be thought of as constituting a conceptual model. The four components of this portion of the evaluation define the linkage between the real-world problem and the conceptual model.

As a first step we must document what information is available on the real-world problem which must be analyzed and the policy and/or other options which may be applied to affect an outcome. This step serves to document the policy context in which the conceptual model is to operate. At the most basic level, the conceptual model would focus on one or more of the four policy issues with which emergency managers are concerned. Specifying the basic policy focus defines which issues are important and how they relate to the real-world problem.

The identification of specific types of policies is the objective of the second component. The way in which specific policies are used to address the problem of interest provides insight and guidance into how one would apply the conceptual model. The reviews in this area seek to identify the basic analysis strategy and restrictions which may affect the model's range of application. This review provides a basis for identifying those resources which may be used or are required to manage the real-world problem. Special emphasis should be placed on relating these resources to the seven mobilization categories used by FEMA.

The third component of the analysis provides the basis for a description of the overall system. Here the evaluator documents the general decision problem and outlines how the various parts of the model fit together. For example, the general problem may fit into one of two broad areas, physical or policy.[1] Additional refinement is accomplished by identifying the analytical/technical approach used in the model. Researchers in applied mathematics usually refer to the possible approach as either descriptive or prescriptive. In a descriptive approach, the solution provided by the model aims at explaining what is happening not why it is happening. In essence, the model provides a snapshot. In a prescriptive approach, the solution provided by the model prescribes the best way to utilize existing resources. Such models explain what should be done; they do not necessarily provide a great deal of insight into what is happening. An example of a descriptive approach is a discrete event simulation where certain components in a network are being modeled during an emergency situation. As the emergency unfolds, certain components of the network function at reduced levels of performance. Performance degradation may cause bottlenecks to develop in the network; if serious enough, they could compromise the entire operation. A simulation model enables the analyst to identify the likely bottlenecks prior to an actual emergency. The basic design of the network may be changed to incorporate this information. Although the design of the new network may be a distinct improvement over the old one, it need not be the optimal configuration. To design an optimal network it would be necessary to make use of specialized optimization techniques. Optimization techniques which are in wide use include linear, non-linear, and dynamic programming.

The final component provides a means for documenting how the model under analysis may have benefitted from previous research. The objective of this step is to see how experience gained from other modeling efforts may have led to the choice of particular algorithms or structural properties. This step serves to sharpen the focus of the evaluation by highlighting the strengths or weaknesses of alternative model specifications brought out in prior studies.

2.2 ORGANIZATION OF THE SUBJECT

This portion of the analysis seeks to develop an outline of the conceptual model. This is done by first cross referencing the purpose of the model with the basic policy issues (mitigation, preparedness, response and recovery) and various emergency-specific measures. Once the relevant policy issues and emergencies have been identified, it is necessary to define the level of detail of the model's output. This entails a critical review of the relevant policy considerations, as well as empirical considerations and modeling/system constraints.

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[1]It is possible for some models to be hybrids, having major components within each of the two areas.

There are three additional steps in the analysis. These steps focus on: (1) software configuration; (2) variable selection; and (3) causal and dynamic relationships. Since these steps are closely related to a number of activities which are carried out under the in-depth review of the documentation, they will be discussed here only briefly. Readers wishing a more detailed discussion are referred to Chapter 3.

In developing a configuration for the software, it is necessary to identify the major elements of the programming approach. This requires the development of a gross-level flowchart which shows all major modules and their relationships to one another. The next step is to determine what information is required to study the problem and why. This would involve both intra- and inter-module transfers of information. More specifically, the criteria for selecting variables should be stated. Variables should also be classified by type (e.g., exogeneous, endogenous, controlled). The final step is to identify the determinants of logic flow and information processing. Since causal and dynamic relationships may drive calculations both within a model or serve to define a hierarchy among modules, it is important that both the criteria used to specify these relationships and their effect on the solutions provided (e.g., convergence) be discussed as an integral part of the conceptual model.

It should be clear from the previous discussion that the conceptual model will exert a substantial influence on both the mathematical model and the operational model. This influence is discussed in some detail in the section which follows.

2.3 THEORETICAL UNDERPINNINGS

This portion of the evaluation has two components. The first is an analysis of the economic and other technical foundations of the model. The second deals with the mathematical characterization of the model, including such properties of the solution algorithm as uniqueness, convergence, and the behavior of successive iterations as the solution is approached.

The first step in the analysis includes the process by which the precise mathematical set of equations is deduced from the conceptual model. An in-depth analysis is required, including a determination of the theoretical basis and structure of the model. A study of basic technological and behavioral assumptions made or implied is also required. The analysis must also consider whether the level of aggregation of activities is appropriate, whether activities are insufficiently modeled, or whether activities that have only marginal significance introduce unnecessary cost and/or complexity.

The mathematical characterization portion of the analysis focuses on developing a thorough understanding of the theoretical foundations of the problem; including references to the open literature where appropriate. It should define the problems solved, describe the mathematical model employed, and document the computational algorithms and numerical techniques implemented in the code. For example, cases where locally convergent procedures are used should be carefully documented. This is because locally convergent procedures are only designed to find a solution near some initial vector of values used to start the iteration procedure. It is important here to recognize that local convergence is being sought and that the initial values of the input vector are crucial to the practical success of the algorithm.

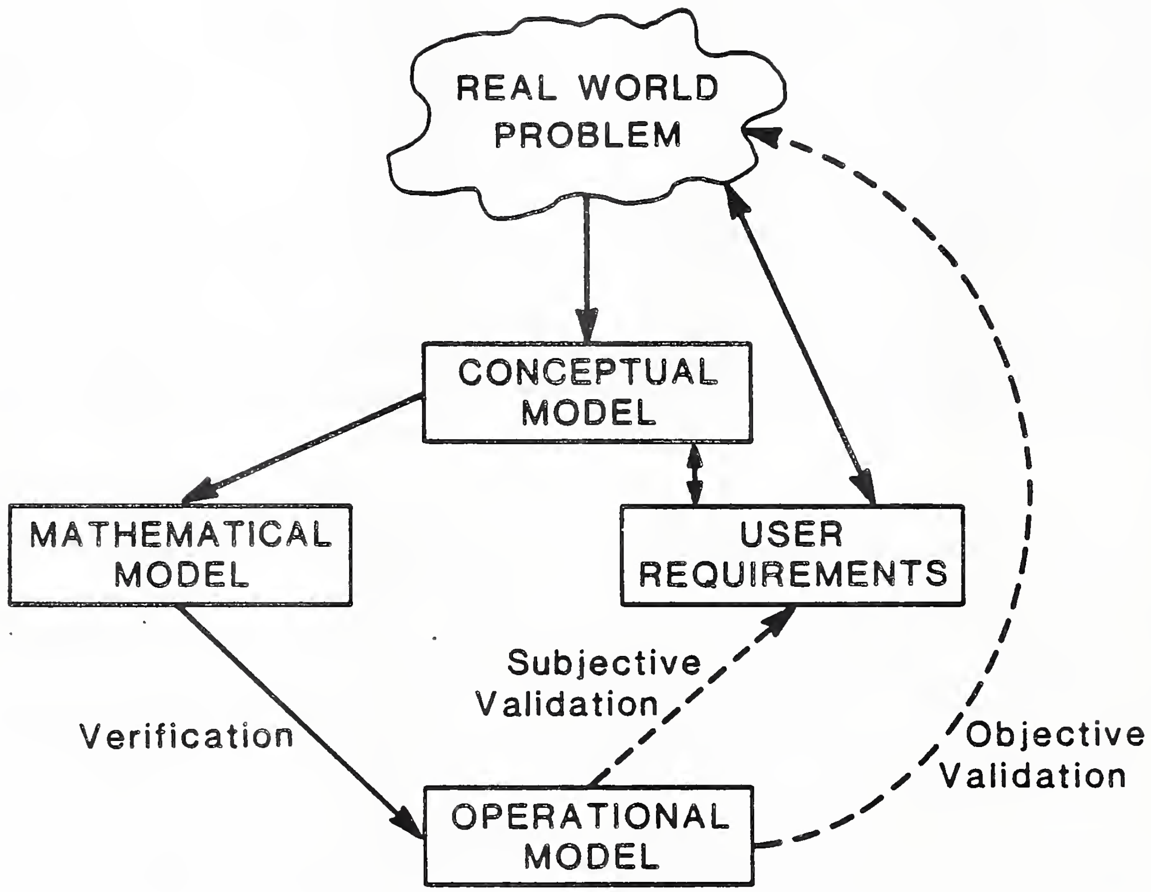
This portion of the analysis should also include a comprehensive description both of the problem solved and of the data processing functions performed. The description of the physical theory in terms of a mathematical model should be reasonably self contained. Sources for the model and the mathematical formulations should be referenced. Sufficient detail is needed to judge the suitability of the model for application to a particular situation. Assumptions should be noted and information given about limitations.

The relationships between the two major components of this activity and the activities described in Sections 2.1 and 2.2 can best be understood through reference to Figure 2.1. This figure shows that there are three distinct types of models which are derived from and related to the real-world problem. These model types are: (1) the conceptual model; (2) the mathematical model; and (3) the operational model. As indicated before, the real-world problem and associated policy issues result in the formulation of a conceptual model. The purpose of the conceptual model is to describe what is to be studied and why. The conceptual model may be based in part on a comparative analysis of the strengths and weaknesses of other models in this problem area or on certain historical information. The mathematical model makes explicit all of the assumptions of the conceptual model; it also specifies the data and domain of definition, statistical properties, and equation structure. The operational model is the version of the mathematical model which resides on the computer system; it is the version of the model which is executed on the computer to address specific policy and/or related issues.

We can now relate the activities of the descriptive analysis portion of the evaluation to Figure 2.1. The methodology described in Section 2.1, motivation for the model, is concerned with the relationship of the real-world problem to the conceptual model. The methodology described in Section 2.2, organization of the subject, serves to define the conceptual model. The economic/technical foundations portion of the analysis documents the correspondence between the conceptual model and the mathematical model. The mathematical characterization portion of the analysis serves to define the mathematical model (e.g., assumptions, data, algorithms, equation structure). The activities which comprise the descriptive analysis portion of the evaluation begin at the top of Figure 2.1, move through the conceptual model to the box labeled mathematical model.

Figure 2.1 also relates the techniques used in a descriptive analysis to the terms verification and validation introduced in Chapter 1. Through reference to the figure we can see that verification is the process of documenting the relationship between the mathematical model and the operational model. Descriptive analysis sets the stage for what follows by outlining the linkage between the real-world problem, the conceptual model and the mathematical model. This linkage should be carefully explained in the model's documentation reports. Both types of validation, subjective and objective, are shown on the figure. Since the conceptual model is an abstraction of the real-world problem, subjective validity implies that the model satisfies both its intended use (as set forth in the conceptual model) and a particular set of user requirements. The ideal case, objective validity, implies that the model closely tracks the real-world problem. Both types of validation are shown as dashed lines to highlight the complexities inherent in "validating" emergency management models.

Figure 2.1 Interrelationships Between Model Evaluation Activities



2.4 MODEL DEVELOPMENT CONTEXT

The final design of a model is often influenced by the practical constraints of resources and schedules. It is useful, therefore, to examine the administrative conditions under which a model was developed and to use this information to alert the user or evaluator to special features of the model which impact on its application or its role in a system of models. The principal constraints which are of interest are resource limitations (project scheduling and the availability of staff) and operational limitations.

Resource limitations must be evaluated in terms of how they impacted the development of the model, especially the time available for theoretical considerations. Resource limitations may result in design freezes, and concessions, and compromises or trade-offs by the model developers on its complexity. The development of a knowledge base for a model evaluation should identify these shortcomings.

Operational limitations which may affect the design of the model include the computer configuration, software support, program language, portability (i.e. the ability to use the program on computers having compatible languages), operational features, turnaround time, and model-to-computer coordination.

The major sources of information about constraints on model development are from documentation. Ideally, the documentation would include descriptions that portray the accommodations made by the developers of the model due to resource or operational constraints. Departures from specifications defined in the contract for the original development and from the description and execution of the acceptance test of the model, which was used to prove compliance with specifications and to test the model's performance and general integrity, should also be documented. Documentation is usually the main model component that is impacted by resource limitations.

The approach for assessing the features of model development, as they relate to the evaluation of the model in the context of user requirements, consists of extracting from the information sources described above, the assumptions, compromises, or trade-offs which resulted from resource or operational constraints, and bringing this information into the evaluation process as described in the guidelines for the model evaluation procedure.

The information presented in this section touches on all phases of the software life cycle. Although model evaluation is carried out with regard to a fixed frame of reference, recommendations are available for the planning and development of new models. One such set of recommendations is summarized in Appendix A.

3. PROGRAM VERIFICATION AND ANALYSIS

This component of the evaluation guidelines focuses on the clarity, completeness and adequacy of the model's documentation. This involves three interdependent activities: (1) an in-depth review of the documentation; (2) a review of the source code; and (3) an analysis of experiences in executing the model.

The in-depth review of the documentation provides the insights which are necessary to perform the remaining portions of the evaluation. Beyond the use of the documentation as a base of technical knowledge is the issue of completeness.[1] This issue is related to the recommendations for program documentation specified in the Federal Information Processing Standards (FIPS) Publication 38[2] and the NBS Special Publication 500-73.[3]

The next activity is to review the source code itself. Any discrepancies between the documentation and the source code should be recorded, especially with regard to their effect on the structure of the program. This review should use the latest techniques of software analysis and code fault isolation.

The analysis of experiences in executing the model consists of several activities. First, any problems in setting up the model on the host system are documented. This step involves interviewing model users and operating system support personnel. Second, the users' or evaluators' experiences in executing the benchmark problem[4] provided by the model developers are recorded. The benchmark problem helps the user/evaluator to determine if the input data are properly communicated throughout the various logical paths of the program. Finally, it is essential that the evaluators document their hands-on experiences with the model. This step documents instances where proper input data are used but errors are introduced through improper data processing. This step also documents experiences in reproducing published results and the ease with which special purpose modules can be used or generated.

3.1 IN-DEPTH REVIEW OF DOCUMENTATION

It is generally accepted that the evaluator needs more to work with than the code which defines the operational model. Current consensus among authorities states that proper documentation is an absolutely essential ingredient for the acceptability and use of any complex computer model.

[1] Gass, S.I. "Documenting a Computer-Based Model," Interfaces, Vol. 14, No. 3, 1984, pp. 84-93.

[2] Guidelines for Documentation of Computer Programs and Automated Data Systems. Gaithersburg, MD: National Bureau of Standards, FIPS PUB 38, 1976.

[3] Computer Model Documentation Guide. Gaithersburg, MD: National Bureau of Standards, Special Publication 500-73, 1981.

[4] A benchmark should be a well-defined problem and solution chosen by the developer to exercise a large portion of the model's logic. This problem should serve as an important vehicle for determining if the model is running properly on the host system.

A substantial body of documentation is required if a model evaluation is to be effective. Researchers at the National Bureau of Standards and elsewhere have identified four basic types of documentation reports which are essential for efficient use of a model. These reports are: (1) Management Summary Manual; (2) User's Manual; (3) Programmer's Manual; and (4) Analyst's Manual. These reports are extremely important in any comprehensive model evaluation. A brief description of each report is therefore given in the text which follows to promote a more complete understanding of the activities involved in an in-depth review of the documentation.

The first manual is designed as a management tool. It provides the information necessary to assess the model's input requirements (including time, money, and other resources) and the usefulness of the model's results. The Management Summary Manual focuses on how the model can facilitate the decision making process rather than the specifics of how to set up and run the model.

The second manual is designed as a reference document for a nonprogramming model user. Information contained in this manual is similar to the first but with increased emphasis on detail. In-depth discussions of the following topics are included: the model's logical structure; the input data requirements; the results produced by the model; and the use of the model results.

The third and fourth documents are designed for use by programmers and analysts, respectively. The third manual provides guidelines for maintaining and modifying the model. These guidelines should be of sufficient detail to enable the programmer to understand the operation of the model and to trace through it for debugging, for making modifications, and for determining if and how the model can be converted to other computer systems. The fourth manual differs from the third in that its emphasis is on the model's functional structure, types of algorithms used, and the techniques employed for model verification and validation.

The first step in this activity is to review the documentation both for its completeness and its clarity. This step greatly facilitates the comparison of the model's purpose and purported capabilities with the user's requirements. Specific tasks within this activity are a determination of what the model is to do and its intended range of application. Issues at stake within this part of the review are the motivation and objectives of the model, its scope and approach, and its assumptions and restrictions.

The document or documents which describe the theory should detail specific information about the model being evaluated. The main goal here is to detail the mathematical methods used and their relationships to the real-world problem. The algorithms used to obtain numerical solutions from a set of relationships (e.g., equations) should be described with references to particular algorithms and numerical techniques provided.

The precision of results obtained by important algorithms and any known dependence on particular types of computers or operating systems should be described. For iterative solutions, the use and interpretation of convergence tests and recommended values of convergence criteria should be included. For probabilistic solutions, the precision of results should be discussed.

A related task is to develop a precise understanding of how the model works. This entails an analysis of the logical flow of data through the model from the entry of input data to the generation of the output. Steps should also be taken to relate the model elements and data flow to the real-world system (e.g., physical elements and information flows). Although particular process equations may be described, documentation providing the rationale for selecting a particular model input or parameter may be missing. Because major uncertainties can arise from uncertainties in specifying the input data, the process for selecting the input must be carefully documented and understood.

Although an analysis of the input data is the subject of Chapter 4 (Data Audit), it is important at the earliest stage to characterize the overall input data structure and the data media. Specifically, for each input variable one should give: (1) the variable name; (2) a description and definition; (3) the source; (4) the procedure through which the data was collected or generated; (5) dimensional units of the variable; and (6) formats for reading the information. It is also desirable to provide information on if or how specific data entries can be updated or, if appropriate, ranges and/or default values which may be set internally.

The interface between the model and the relevant data files must also be covered in the documentation. Details which specify the names, usage (input, output, scratch) and structure of external and temporary data files should be provided. This includes a discussion of program procedures related to the use and maintenance of data files.

As the review of the documentation progresses, the evaluator should focus on the development of a complete technical description of the model with particular emphasis on its operational details. The documentation reports which focus on a description of the source program should provide the basis for this activity. These reports should include: (1) the identification of the source language (e.g., FORTRAN 77); (2) references to any relevant software standards (e.g., ANSI X3.9-1978); and (3) a flow chart showing the overall program structure and logic, and, where appropriate, detailed flow charts.

Most complex models contain certain programming considerations which are important for successful implementation. At least four are of sufficient importance that they should be checked against the existing documentation. First, the system control commands required to execute the program (including options) must be clearly explained. Second, the storage allocation and data management procedures should be described. Special attention should be paid to any requirements for storage and/or data manipulations which are problem dependent. In such cases, alternatives which affect data storage and use should be discussed. Third, the overlay or segmentation scheme for the model should be documented. Finally, any restart, recovery or successive case capabilities should be discussed. This issue could be of critial importance where models are used in the emergency response mode which may entail operation in a hostile environment. Provisions for graceful degradation of service and manual operation and/or restart should therefore be carefully explained and related to the real-world problem.

. Many of the issues raised in the previous discussion touch upon the topics of usage and transportability. This part of the documentation review seeks to describe how the model is to be used and what steps are necessary to run it on another computer system. Critical factors which affect both the ease with which a model can be used on one system or set up on another are: (1) a run-stream description; (2) a sample model run; (3) a discussion of options; (4) an interpretation of the model's output; (5) a guide to troubleshooting when executing with user-generated data; and (6) a set of provisions for software exchange. At a minimum, the first four factors should be addressed in the documentation, if the model is to be either usable or transportable.

The operating system control commands (either as generic statements or as card images) required to execute the program should be given with an indication of any interdependencies with either input options or data files. The program output should be described with relationships shown. Any normalization of results should be described and associated dimensional units listed. Whenever the model is transferred from one system to another, the relevant standards governing information transfer should be followed. This would include computer-readable material written on magnetic tape which lists as separate files: (1) the source code; (2) any auxiliary code; (3) a benchmark data set; and (4) the output from running the benchmark data set.

3.2 REVIEW OF SOURCE CODE

This portion of the evaluation determines whether the operational model runs as intended by the developer. More precisely, we determine if the source code checks against the mathematical model described in the documentation reports. Deficiencies can arise, both in the translation from statement of purpose to model formulation, and in the translation from the mathematically stated model to the source code. Determining the equivalence of the two, or documenting the differences, is an important part of the evaluation process. The source code is checked carefully against the model specification, as determined from existing documentation and augmented where necessary with supplemental information provided by the model evaluator. Critical issues which are analyzed include: (1) the relationship between assumptions as stated in the documentation reports and as they are written into the code; (2) the identification of critical sets of calculations; (3) the identification of hard-wired parameters or sections of logic which are by-passed; and (4) the effect of default settings.

The input data must also be shown to be properly communicated throughout the various logical paths of the computer program. It is possible for the equations to be properly programmed and for the input to be read correctly, but for subsequent difficulties to be introduced through code default values or improper data processing.

It is important to point out that the review of the source code should be selective. The earlier review of the model's documentation should provide insights as to where important information is read, transferred or output. It is these areas where a line-by-line review of the code should be focused. This review may make use of debugging options which allow for tracing or for checking the values of arguments in an array.

A thorough review of the source code should produce several tangible benefits. First, it should classify the role and function of the MAIN program and each subprogram. Second, for each subprogram, it should indicate those subprograms which call it and, in turn, those subprograms it calls. Third, it should provide an understanding of how problem variables and constants relate to program mnemonics. Fourth, it should critically examine the relationship between the actual model outputs and those described to the users in the documentation reports. This review may focus on a variety of topics ranging from a check on formats used to create output, to the effect of options and print switches on the form and substance of the output. Fifth, it should identify all shared storage assignments (e.g., COMMON statements in FORTRAN). Sixth, it should identify the series and the level of the operating system, language processors, and associated subroutine libraries invoked by the model. Finally, it should describe known deviations from the manufacturer's supported software that are required by the model (e.g., local mathematical and utility routines, and other installation-dependent software).

There is a major benefit to the model user associated with an independent review of the source code. The evaluator, by cooperating with the model user and developer, can provide some documentation, if necessary, rather than pointing out that certain key components are incomplete or missing. Naturally, the documentation provided by the evaluator is not always fully consistent with the views of the modeler. However, if the evaluator helps to provide the necessary documentation about the condition of the model and resists the temptation to improve or replace specific features without the concurrence of the modeler, then they make a contribution that outweighs any potential disadvantage.

3.3 IMPLEMENTATION OF THE MODEL ON THE HOST SYSTEM

This portion of the evaluation focuses on three activities. The first activity aims at developing information which documents the model's operating characteristics. The second activity seeks to determine what special attributes of the host system were built into the model. The third activity documents information on the user's perception of the model.

Only the first activity is traditionally included in the documentation for the model. Unfortunately, the statistics which are generated on run times, execution costs and core requirements for the host system should be viewed as machine dependent.[1] However, if the cases which are analyzed and used to generate these statistics are carefully chosen, they can teach the user a great deal about the relative cost and efficiency of running the program on the host system.

In the previous section, we discussed how a critical review of the source code could help to determine what special attributes of the host system were built into the model. Another source of information on this subject is the current set of users on the host system. Interviews with the users may produce

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[1]Unless the model has been run on different hardware/software configurations, these statistics may provide only a rough idea of what it would be like to run the model on another system.

information on their experiences in replicating the benchmark problem or of specific tests which they may have run to test their hypotheses about how the program works. It may also be possible to review memos written while the model was being built which document time or funding constraints which may have had an adverse effect on the final product (see Section 2.4).

The last activity seeks to evaluate the user's perception of the model. Information collected here is of particular value in determining if the model is useful, if it is usable on the host system, and if it is being used as a decision-aiding tool. To obtain this information it is necessary for the evaluator to interview the users of the model. There are several issues which need to be addressed in order to provide a basis for a more detailed evaluation of model usability. First, the evaluator must determine how the user's understanding of the model affects their perception. For example, casual users may believe the model is too "data intensive" or "output oriented," whereas more frequent users may have concerns about how to combine options to address a specific policy issue. Second, whenever someone works with a large-scale model over an extended period of time, they encounter problems. The source(s) of the problem(s) may be due to user error or to faults within the program. If it is possible to document some of the more common problems (either real or perceived), they may provide valuable information regarding the usability of the program. Finally, the user's assessment of the flexibility of the model must be carefully documented. It is important to qualify how the term flexibility is being used because there are two notions at work. The first notion of flexibility deals with the nature of emergency management. Emergencies by definition are low-probability and/or high-loss events. The model should be designed so that certain variables (including coefficients) can experience large changes in value and the model will still converge.[1] The second notion of flexibility deals with the way in which specific policy issues are addressed. For example, the model may require the values of certain inputs to be preset. The question would then be how to relate a specific policy to a particular input or set of inputs. Is the relationship clear? Would someone else select the same variable or set of variables?

3.4 DOCUMENTATION OF EVALUATOR'S HANDS-ON EXPERIENCES

A thorough evaluation requires hands-on experience with the model in question to fully understand the requirements for its effective use. Hence, this task must include the facility and organizational arrangements that permit access to the model either remotely or by conversion and operation on the evaluator's computer system. Regardless of whether the model is run on the host system or on the evaluator's computer system, it is essential that the computer code be frozen at some point in time so that the evaluation can be conducted with respect to a fixed frame of reference.

The first activity which must be documented is the relative ease with which the model can be used. This includes an estimate of the time it takes to learn enough about the model to perform a meaningful analysis. The precise specification of the model, as executed in terms of documentation, data and control statements, should be given so that processing considerations can be

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[1] No assertion is being made that the value to which the model converges is correct. We only require here that the model produces a solution.

evaluated. The experiences of the evaluation team can serve to further document the model's operating characteristics. For example, statistics on run time, execution costs and core requirements can be compared to any which may have been reported in the documentation reports.

A related topic is the evaluator's experience in obtaining solutions and replicating published results. The main activity here is to identify those model attributes which promote or complicate its use by third parties. For example, in performing a sensitivity analysis, it may be necessary to construct a coordinated set of runs. If the method of model sampling is used (see Chapter 5), the model is run according to a prespecified experimental design. This may require special purpose routines. It is therefore necessary to determine whether such special purpose routines are easily generated. Specific issues which must be addressed include: (1) modifications to the model's basic logic flow; and (2) any input and/or output considerations.

A major benefit of the evaluator's hands-on experiences with the model is an assessment of the adequacy of the model's maintenance plan. Large models which are used as inputs to policy analysis are constantly being changed. Three issues are of crucial importance on a model's software maintenance plan; they are: (1) unscheduled updating; (2) periodic updating; and (3) review. Unfortunately, unscheduled updating is the most common; it is also the least conducive to adequate software maintenance. Unscheduled updating occurs when errors are found in the program which entail code changes. Since the code changes are often made with a view towards what is happening locally, large sections of logic in other parts of the program may inadvertently get altered or turned off. Similarly, new program applications may be identified causing the model to be pressed into a service for which it was not originally designed. On the other hand, periodic updating is usually associated with cases in which the entire data base or key portions of the data base are revised. It is also possible that empirical relationships will be reestimated, producing new values for key parameters. These activities may result in a new set of documentation reports or an abridged version which documents the changes which were made. For example, all major input-output tables which are based on the Department of Commerce benchmark are on a five year updating cycle. The fact that model documentation may be adequate at one point in time does not imply that it will be adequate at some future date. In order to insure that the software is maintained properly and the documentation is kept up-to-date, it is necessary to have a formal review procedure. This procedure should document both the strengths and weaknesses of the model. The end result of the review is whether the model should continue in use as is, be modified, or not be used. It should be clear that once a model has been subjected to a critical evaluation, a procedure which calls for periodic reviews would be a logical followup.

4. DATA AUDIT

The confidence which a user or decision maker has in a model, and therefore its utility, are increased significantly if one can document the sources of the data. It is also desirable to show that the projected impacts of the input data uncertainties on the calculated responses of interest are sufficiently small that they do not invalidate the intended uses of the model. The focus of the data audit is therefore on the accuracy and internal consistency of the data base.

The data audit portion of the evaluation requires: (1) review and clarification of data definitions; (2) analysis of the nature and structure of the data base; (3) determination of data sources; (4) analysis of the file computerization and accessibility and (5) analysis of the quality of selected important data by estimating uncertainties as bounds.

Specific techniques which should be applied as an integral part of the data audit are based both on exploratory data analysis and classical statistics. Due to their interactive graphical analysis capabilities, software packages such as DATAPLOT[1] are especially attractive for performing a data audit. These techniques are essential to any thorough evaluation because they facilitate the analysis of descriptive, relational and structural properties of the data base. This information is particularly useful in analyzing the interactions between a particular model and data base. Special attention should be placed on identifying and determining the extent of any data-imposed constraints on model formulation.

4.1 IN-DEPTH REVIEW OF DOCUMENTATION

Many of the items associated with an in-depth review of the model's data files have already been discussed in Section 3.1. Since the model and its data files are closely related, the information used to perform a data audit are discussed in all four documentation reports. From a practical standpoint, however, one would expect that more emphasis would be placed on data issues in the User's Manual and Programmer's Manual. This is because these reports are concerned with the everyday running of the model and its maintenance procedures, respectively.

At the most basic level, these reports should describe the overall input data structure and the data media (e.g., tape, cards, disks). They should include a table that shows the input data file names, their media, and any general data limitations. The table(s) should also describe the interdependencies, if any, among input data files.

Specific data inputs are normally organized in related groups or as data records that are entered on a card image. These related groups of data establish and define a data file and should be described together. The input data files and the items within each data file should be discussed in the order of their appearance in the run stream.

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[1]Filliben, J.J. DATAPLOT - Introduction and Overview. Gaithersburg, MD: National Bureau of Standards, Special Publication 667, 1984.

Any detailed description of a data file should include four items: (1) the file's name; (2) the number of inputs; (3) a list of related data files; and (4) a description of data records. The first item should give an overview of the data file's contents and its purpose. The second item should include any factors which influence the total number of inputs from the data file, as well as the maximum number of records that may (or must) be used to execute the model. The third item lists any data files whose contents depend on or dictate the input values of the file under analysis. The fourth item provides general comments on the format of the data records followed by a description of each of the data records.

The preferred approach for summarizing the information on the four items just described is through the use of a data dictionary. A comprehensive data dictionary consists of two parts: (1) a dictionary of input variables; and (2) a dictionary of internal variables. Both dictionaries should be arranged in alphabetical order by variable name.

The dictionary of input variables provides an in-depth summary of all input terms. Each array dimension should be defined and, where applicable, references should be made to the effects caused by variable settings in other parts of the input deck. If it is necessary to refer to a specific element within an array, then a labeling convention should be adopted and used throughout the dictionary. A mnemonic which helps associate the variable with its purpose should also be given. For example, the key letters in the related name may be capitalized and/or underlined. The specification through which the variable is read into the program (e.g., variable type in a FORMAT statement) should then be given. It is also necessary to describe where within the model the variable is read. If the variable has a range, the range should be given. If the input data are constructed through a series of worksheets, then the variable should be cross-referenced to the appropriate worksheet. A complete definition of the input variable should then be given; any additional information should also be noted at this time.

The dictionary of internal variables focuses on those variables which are used for intermediate calculations and hence are not directly under the control of the user. Ideally, four types of variables should be included in this dictionary: (1) any variable which appears in an output report but is not an input; (2) any variable which appears in a COMMON statement; (3) any variable which is passed as an argument in a call to a subprogram; and (4) any variable which appears in a DIMENSION statement but is not otherwise covered. The discussion in the dictionary of internal variables should parallel that of the dictionary of input variables. The major purpose of this dictionary, however, is to provide enough information to enable programmers to make changes to the source code dictated by either user needs or operating system characteristics.

An important part of model usability is data collection. Explicit instructions for data collection and maintenance should therefore be included in the appropriate model documentation reports. These instructions should include the identification of the parties responsible for data collection and maintenance.

At the most basic level, the documentation reports should discuss the data sources for each data file. The discussion should identify the form in which the raw data are available, and if appropriate, other organizational units from which the data may be collected. Any special statistical or other techniques used to obtain or generate the data should be carefully explained. A flow chart that illustrates the major data collection steps and their sequence is highly desirable. Updating procedures should also be explained. The documentation reports should provide step-by-step instructions for maintaining the data files. If other programs are used to update the data files, they should be identified and instructions for their use given. As before, a flow chart that illustrates the major updating procedures and their sequence should be included.

4.2 ANALYSIS OF FILE COMPUTERIZATION AND ACCESSIBILITY

A variety of items should be checked to ensure that the data files have been properly mechanized. Some of the information on these items will be uncovered during the review of the model's documentation reports and some will be uncovered during the review of the source code. Information uncovered in the documentation review which affects file mechanization should include: (1) an outline of the general contents and organization of the data files; (2) references to other programs which create, modify or edit these files; and (3) the relationship of the data files to the execution of the program. Additional information governing special input techniques and requirements, the handling of consecutive cases and the general conventions governing default values should also be a natural by-product of the documentation review. Information uncovered in the review of the source code focuses on such items as: (1) the dimensions of data arrays; (2) the dependence of data storage requirements on problem input parameters; (3) the restrictions on the range of values of variables; (4) the program's restart and recovery procedures; and (5) the program's error messages and their causes.

A critical component in the analysis of file computerization is a description of all data structures internal to the model. This description should focus on both local and global variables, arrays and data records.

Local data structures should contain the meaning and purpose of all local variables, arrays and data records (local data structures have their values defined only within particular routines). To promote a better understanding of the file, local data structures should be associated with the subprograms in which they appear.

Global data structures should contain the meaning and purpose of all global variables, arrays, and data records (global data structures are defined throughout the model).

The relationship between local data structures, global data structures and specific data files can be understood better by adopting the following convention: (1) general data are summarized in tables; (2) organizational characteristics are summarized in figures; and (3) the contents of a specific file are listed in exhibits. The tables focus on generic information only (e.g., variable name, format, purpose, range, etc.). Cross-referencing between exhibits, figures and tables should be sufficient to enable the programmer and/or evaluator to understand how the model approaches an application problem.

Global data structures must be made available to the various subprograms of the model. The most frequently used method is COMMON storage. By using the COMMON storage accessing method, frequently used data may be referenced by the same mnemonic throughout the program. The variables in the COMMON storage areas may be the user's input, or program defined data which may be character, integer or real. No particular ordering is used in assigning variables to the areas. However, those areas used for user's input are allocated in the same order as the input records. The documentation reports should contain a description of COMMON storage areas. These descriptions should present a synopsis of the type of variables stored in each area as well as a listing of variables in each area. A series of tables listing the variable name (including dimensions for arrays), its contents, ranges on values, and data type (e.g., character, real, integer) should be sufficient for cross-referencing.

Most large-scale models produce two basic types of outputs, normal outputs and error messages. The normal outputs have been discussed under several headings in Chapter 3. Error messages were mentioned earlier; they are used to address the everyday problems of incorrect formatting, recording and sequencing errors in user-generated data. They are also useful in identifying inconsistencies within a data file. If the model is at all complex, it should contain a system for edit-checking the values of key input variables. If an error is encountered, a message should be printed out to the user to help locate the source of the error and then correct it. The model's documentation should thus include a description of the error messages output with suitable cross-referencing to the input deck and/or data file. The description of the error message should include: (1) the diagnostic (i.e., the error message output to the user); (2) the action taken (e.g., program terminates or said variable is set to its maximum or minimum allowable value); (3) the data output (e.g., the value read, the maximum value allowed, or the column number of an array undergoing a transformation); and (4) the remedy (e.g., check the settings on read loops, check the sequencing of card images, check for missing data). Care should be taken so that the description offers sufficient detail to enable the user to locate and correct the error based on the prescription given in the remedy. Any instances where error messages are suppressed due to settings on print switches should also be given to alert the user that it may be necessary to look for second-order effects.

4.3 SPECIALIZED TECHNIQUES: AN OVERVIEW

Specialized techniques for a data audit may focus on two distinct types of data analysis: (1) internal; and (2) external. In an internal data analysis quantitative comparisons may be made across records for a given variable, across variables for a given record, or across time for a given variable. In an external data analysis quantitative comparisons are made to comparable data in other data bases or in published documents. The focus of this section is on an internal data analysis.

An internal data analysis has three basic objectives. The first, and most basic, is to produce a frozen, archived and documented data base ready for efficient computer analysis. The reasoning here is the same as in the case of program verification and analysis, namely, the data audit must be conducted with respect to a fixed frame of reference. The second objective is to produce a general understanding of the data file(s). This includes: (1) a general understanding of the key variables; (2) a rough cut at response meaningfulness in terms of agreement to definition and consistency; and (3) a qualification of the types of error present. The third objective is a quantification and summary of the probable errors and/or error patterns present in the data files.

A number of researchers have stressed the potential for performing two fundamentally different forms of quantitative data analysis. These methods are (1) the exploratory data analysis techniques of Tukey; and (2) classical statistical techniques.

Exploratory data analysis is concerned with isolating patterns and features of the data and with revealing them clearly to the analyst. Ideally, exploratory data analysis provides the first contact with the data, preceding any firm choice of model for either deterministic or stochastic components. Exploratory data analysis is particularly useful in uncovering unexpected departures from familiar models or the assumptions upon which these models rest. An important element of the exploratory approach is flexibility, both in tailoring the analysis to the structure of the data and in responding to patterns that successive steps of the analysis uncover.

Specific techniques in exploratory data analysis are based on four major themes: (1) resistance; (2) residuals; (3) re-expression; and (4) display. Resistance is a matter of insensitivity to "misbehavior" in data. More formally, an analysis or summary is resistant if an arbitrary change in any small part of the data produces only a small change in the analysis or summary. For example, in summarizing the central tendency of a sample, the median (the 50th percentile) is highly resistant. By contrast, the mean is highly non-resistant. Consequently, a number of exploratory techniques for structured forms of data provide resistance because they are based on the median.

Residuals are what remains of the data after a summary or fitted model has been subtracted out. The attitude of exploratory data analysis is that an analysis of a set of data is not complete without a careful examination of the residuals. This emphasis reflects the tendency of resistant analyses to provide a clear separation between dominant behavior and unusual behavior in the data. When the bulk of the data follows a consistent pattern, that pattern determines a resistant fit. The residuals then contain any drastic departures from the pattern, as well as the customary chance fluctuations. Unusual residuals suggest a need to check on the circumstances surrounding these observations.

Re-expression involves the question of what scale would help to simplify the analysis of the data. Exploratory data analysis emphasizes the benefits of considering, at an early stage, whether the scale in which the data are originally expressed is satisfactory. The re-expressions most often used in exploratory data analysis come from the family of functions known as power transformations together with the logarithmic transformation.

Displays meet the analyst's need to see behavior (of the data, of fits, of diagnostic measures, and of residuals) and thus to grasp the familiar regularities.

Graphical analysis packages such as DATAPLOT incorporate all four themes of exploratory data analysis. DATAPLOT is a FORTRAN-based, interactive high-level language for data analysis and graphics. There are six reasons why packages like DATAPLOT are recommended for use in a data audit. First, the use of graphics takes full advantage of human pattern recognition capabilities. Second, graphical techniques make use of a minimal number of assumptions, which has as an important consequence that the conclusions are less likely to be approach dependent. Third, from a communications point of view, graphics are generally a much more understandable and efficient way of conveying information to others than is a set of summary statistics. Fourth, graphics allow the analyst to see and use all of the data. In forming a summary statistic, this is generally not true, since information latent in the entire data set is mapped into a single number. In general, the statistic is only sensitive to one particular analysis aspect of the data. Fifth, graphics permit the analyst to check many different aspects of the data simultaneously. Information will therefore be relayed not only about what is being investigated, but also about unsuspected anomalies in the data. Finally, graphics complement classical statistical analysis techniques. This point will become more clear as specific techniques are described. Three types of exploratory data analysis techniques which can be performed with DATAPLOT are related to measures of: (1) central tendency; (2) distributional form; and (3) relational properties.[1]

The use of classical statistical analysis in a data audit serves to focus on the same broad areas as exploratory techniques, namely, central tendency, distributional form, and relational properties. Measures of central tendency usually reported in statistical analysis packages include the mean, the median and the mode of the sample. Measures of dispersion include the variance and the standard deviation of the sample. Measures of distributional form include such statistics as skewness and kurtosis based on the moments of the distribution function as well as histograms and goodness-of-fit tests. Classical techniques for analyzing relational properties are correlation and multiple regression. Box-Jenkins techniques are also of great value in promoting a more complete understanding of data having a time dimension.

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[1] A detailed description of a wide variety of statistical techniques for performing a data audit is provided in Appendix B.

5. SENSITIVITY ANALYSIS

Sensitivity analysis deals essentially with the response of a model to perturbations (changes) among its state and data variables. All of the methods of sensitivity analysis address this underlying relationship. The techniques, however, differ in the way they analyze perturbations, depending on the nature of the perturbation and its manifestation in the model formulation and design.

Conventional wisdom dictates that models may only be validated within given constraints for a specific application. From a different perspective, however, it may be possible to validate a model in a universal sense if knowledge of the subject is known beyond scientific doubt or is automatically acceptable as a representation of a process. The techniques used in sensitivity analyses are themselves models of the distributional behavior of error, and are, therefore, subject to the same scrutiny afforded other models. On the other hand, the collective evidence of information gained from the methodology provides a powerful component to model evaluation procedures.

5.1 A NOTE ON METHODOLOGY

Sensitivity analysis is usually essential in developing information necessary for a comprehensive assessment of model performance. It serves not only in the generation of information, but contributes to understanding the model's competence and its range of application to policy issues.

Since sensitivity analysis deals, in a broad sense, with model response to some condition or perturbation, an analysis of the response depends on: (1) the type of model under evaluation; (2) the nature of the condition or perturbation in effect; and (3) the way the response is measured and described. These three factors form the basis for a wide variety of analytical techniques which collectively constitute the methodology of sensitivity analysis.[1,2]

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[1]For an in-depth review of the theoretical and empirical considerations in the literature on sensitivity analysis, the interested reader is referred to: Hendrickson, R.G. A Survey of Sensitivity Analysis Methodology. Gaithersburg, MD: National Bureau of Standards, NBSIR 84-2814, 1984.

[2]Two advanced topics in the theory of sensitivity analysis which have important applications in the evaluation of policy-oriented models are summarized in: Harris, C.M. Issues in Sensitivity and Statistical Analysis of Large-Scale, Computer-Based Models. Gaithersburg, MD: National Bureau of Standards, NBS GCR 84-466, 1984.

In order to evaluate a model it may be necessary to develop information on model performance in one or more of the following problem areas from which error or uncertainty may originate: (1) errors associated with the mathematical formulation of the subject; (2) importance analysis, which is an assessment of weak or non-contributing data, representations, or levels of aggregation in the design of the model; (3) statistical properties and bounds of the model response under stress or test scenarios; (4) stability, the model's behavior to certain rare or unexpected conditions; and (5) robustness, the performance of the model when some or all of the assumptions on which the model design was based are ignored. Each of these areas of potential interest embrace a variety of forms the problem may take. Consequently, the evaluation procedures which are invoked to develop performance information in these five areas are themselves generally grouped along appropriate lines of formal mathematical and statistical analysis.

The subject of error analysis covers a wide variety of types of errors which may be encountered during the evaluation of a model or in a database audit. The variety includes numerical errors in data, significance of values in data sets, functional error analysis traditionally measured by means and variances of functions and represented by sensitivity coefficients (partial derivatives), propagation of errors through estimated computations in subroutines or algorithms, and sensitivities as measured by Lagrange multipliers.

The objective of importance analysis is to identify those variables, or subsections of a model, which do not appreciably affect the application of the results of the model. The determination of the relative weakness of variables, data, or model components is generally a subjective matter to be decided by the evaluator. Identifying these non-contributing elements, however, may lead to model simplification, modification of databases, or to the elimination of unnecessary complexity in the functional representation of activities.

Statistical analyses are the most widely used methodology of sensitivity analysis. They include the calculation of mean, variance, confidence or tolerance limits, regression and polynomial fitting, hypothesis testing, goodness-of-fit, covariance, estimates of statistical parameters, and distribution-free techniques. The information about model performance gained from statistical computations may be used to analyze non-stationarity, distributional properties, variation of output, and other measures of sensitivity of a stochastic nature.

Model stability encompasses three different manifestations of response: (1) the relation of domain to range; (2) transition points in model behavior as a function of parametric trajectories; and (3) the existence of cusps, or catastrophes, within the model design. If the model is viewed as a mapping of input data (domain) into an output set (range), then the evaluator is interested in any anomalies in this operation which introduce abnormal results or mappings which imply an increase in error or decrease in the confidence of the output.

Transition points are defined as those points at which the expected character of the model behavior undergoes a significnt alteration. They indicate to the evaluator that the output has taken a new direction, but are regarded to be less critical than the cusp or catastrophic transition. The transition which is a catastrophe is one in which a critical state variable of the model has suddenly undergone an abrupt change of value. It usually represents either an adjustment of the model to stress or it is a rapid minimizing response to unstable conditions. The points of transition are directly related to values of parameters which pursue a path in control space (parameter trajectory). The path, if it moves into an unstable region may produce either smooth transition of a state variable or it may trigger a cusp or catastrophe response, which is a discontinuous jump in the state variable. Parameter tracking becomes, therefore, an important activity in the study of model stability.

Robustness in statistics is the attribute associated with a method which is successful although the underlying assumptions for its application are violated. In a similar way, a model may be said to be robust if it can be used for scenarios it was not designed to address, or that it may be used successfully when its use violates underlying assumptions inherent in its design or formulation. Errors which arise in this context should be studied directly in terms of the assumptions themselves, and also in terms of the model behavior to the direct or indirect impact of these assumptions on the formulation of the subject.

If a model displays robustness and can therefore be applied to policy problems beyond those for which it was originally designed, it is desirable to determine, as part of the evaluation, its <u>range of application</u>, and to use this information to establish and understand the model's relationship and power to similar models of its own class, and to identify the scope of its multiple capabilities with respect to models assigned to other classes of performance.

In addition to the numerical accuracy and significance of input data it is necessary to recognize two additional sources of error: system noise and the error of observation. If the data are not a time series then the analytical techniques associated with the classical theory of errors are adequate tools of evaluation. If, however, the data set is a time series, then the errors are examined according to the model of the series and the intrinsic properties of the data. The range of models for time-series studies is quite large: regression at the lowest level, through polynomial and autoregressive formulations to autoregressive, integrated, moving average (ARMIA) models for non-stationary time series.

5.2. THE METHOD OF MODEL SAMPLING

Recent work by McKay, Conover and Beckman[1] and by Harris[2,3,4] has produced techniques which permit the effects of uncertainty to be rigorously analyzed. Their approach makes use of the method of model sampling. The method of model sampling is a procedure for sampling from a stochastic process to determine, through multiple trials, the nature and effects of a probability distribution that would be difficult or impossible to determine by standard statistical means. The method of model sampling, or distribution sampling as it is also called, has a long history of use by statisticians to derive distributions empirically that are difficult or impossible to derive by other means.

Although the method of model sampling is described as an analytical technique for performing a sensitivity analysis, it is also one of the most appropriate tools for generating answers to "what if" type questions for policy analyses.

The method of model sampling is ideally suited for carrying out a structured sensitivity analysis. In this case, information on the probability distribution for each variable of interest, x_i, $F^i(x_i)$, is available from the data audit. Uncertainty about the values of the x_i can then be handled by treating them as random variables. In turn, this information may be used to make inferences about the probability distribution of the output. The mechanics of the method of model sampling involves a "numerical" experiment which characterizes the distribution of the model's output. In essence, the experiment searches for an unknown transformation, h(X), of the vector, X, each of whose components has known probability distributions, $F^i(x_i)$. Clearly, several sets of values of X, say X_1, ..., X_N, must be selected as successive sets of inputs in order to determine the probability distribution of the output.

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[1]McKay, M.D., W. J. Conover and R. J. Beckman, "A Comparison of Three Methods for Selecting Values of Input Variables in the Analysis of Output from a Computer Code," Technometrics, Vol. 21, No. 2, 1979, pp. 239-245.

[2]Harris, C. M. "An Assessment of Climatological Uncertainties Using Monte-Carlo Analysis," in Selected Assessment Strategies Applied to Short-Term Energy Models. Gaithersburg, MD: National Bureau of Standards, NBSIR 83-2672, pp. 30-54, 1983.

[3]Harris, C. M. Issues in Sensitivity and Statistical Analysis of Large-Scale, Computer-Based Models. Gaithersburg, MD: National Bureau of Standards, NBS GCR 84-466, 1984.

[4]Harris, C. M. Computer Generation of Latin Hypercube Sampling Plans. Gaithersburg, MD: National Bureau of Standards, NBS GCR 84-476, 1984.

There are a variety of methods available for selecting the values of the vectors. The three most popular methods are: (1) random sampling; (2) stratified sampling; and (3) Latin hypercube sampling. Random sampling has intuitive appeal in that an entire body of statistical literature may be used to make inferences about the distribution of the output. In a numerical experiment based on the method of random sampling, the values $X_1, \ldots, X_N$ are a random sample from the individual distributions, $F^i(x_i)$. Although this method produces unbiased estimators of the parameters of the distribution, it does not guarantee that the observations are reasonably spaced over the full range of the probability distribution. This problem may be quite serious if low-probability occurrences (i.e., those in the tails of the distribution) are of importance. In addition, there is no guarantee that values are not duplicated, which could waste sampling resources.

Some of the difficulties with the method of random sampling just mentioned have been used to justify the use of another method, stratified sampling. In this method, all areas of the sample space S of X are represented by input values. Let the sample space S of X be partitioned into I disjoint strata, S_i, of size

$$p_i = P_r(X \in S_i)$$

where

$$\sum_{i=1}^{I} p_i = 1$$

Let x_{ij}, $j=1, \ldots n_i$, be a random sample from stratum S_i, where

$$\sum_{i=1}^{I} n_i = N$$

As was the case when the method of random sampling was used, stratified sampling produces an unbiased estimator of the mean of the output distribution. However, the variance of the output is less when stratified sampling is used than when random sampling is used. If the probability sizes, p_i, of the strata and the sample sizes, n_i, are chosen so that

$$n_i = p_i N$$

then a proportional allocation is achieved. Tocher[1] has shown that if stratified sampling with proportional allocation is used, then the variance of the output distribution is reduced further. This implies that any stratified plan which employs subsampling, $n_i > 1$, can be improved by further stratification. This leads to a special case, proportional allocation with one sample per stratum. As we shall see shortly, there is a relationship between this case and the third method, Latin hypercube sampling.

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[1]Tocher, K. D. The Art of Simulation. Princeton, NJ: D. Van Nostrand, 1963, pp. 106-107.

In stratified sampling the range space S of X can be arbitrarily partitioned to form strata. In Latin hypercube sampling the partitions are constructed in a specific manner using partitions of the ranges of each component of X. Consider the case where k components of X are of interest. For simplicity, we may assume they are the first k components. Let the ranges of each of the k components of X be partitioned into N intervals of probability size 1/N. The Cartesian product of these intervals partitions S into N^k cells each of probability N^{-k}. Each cell can be labeled by a set of k cell coordinates

$$M_i = (m_{ij1}, \ldots, m_{ijk})$$

where m_{ijk} is the interval number of component x_k represented in cell i. A Latin hypercube sample of size N is obtained from a random selection of N of the cells $M_1, \ldots, M_N$, with the condition that for each jk the set$\{m_{ijk}\}i=1,N$ is a permutation of the integers 1, ..., N. The columns of permutations, jk, of the integers 1, ..., N, must also be created in such a way that there is no duplication in any row. One random observation is made in each cell. The method so obtained can therefore be considered a k-dimensional extension of Latin square sampling.

McKay, et al, were able to show that Latin hypercube sampling schemes provide the most efficient means for empirically estimating the distribution function of the output as well as the parameters of the distribution for a limited number of trials. One additional advantage of Latin hypercube sampling results when the model's output is dominated by only a few components of X. This is because the Latin hypercube sampling method ensures that each of those components is represented in a fully stratified manner, no matter which components might turn out to be important.

Whereas the construction of nonrandom Latin hypercube sampling schemes is not a hard problem, the construction of random Latin hypercube sampling schemes is a nontrivial exercise. Recent work by Harris has resulted in a procedure for generating large-scale random Latin hypercube sampling schemes via a computer code. This code uses as arguments the values of N and k. For example, if the distribution of each of four random variables was divided into ten equally probable increments (i.e., N=10, k=4), then the procedure would generate a sampling scheme such as is shown in Table 5.1. For this simple case, ten simulations would be performed in the "numerical" experiment. The probability distribution for each variable $F^1(x_1)$, $F^2(x_2)$, $F^3(x_3)$ and $F^4(x_4)$ is divided into 0.10 increments. Since N is even, the median of each increment is used (i.e., the 5th, 15th, ..., 95th percentiles) for the value of the random variable x_i. Through reference to Table 5.1 we see that the first simulation would have variable x_1 set to the 65th percentile of its distribution, x_2 to the 15th percentile, x_3 to the 45th percentile, and x_4 to the 55th percentile.

Table 5.1 A Typical Randomly Generated Latin Hypercube Sampling Scheme

	Variable			
Simulation	x_1	x_2	x_3	x_4
1	7	2	5	6
2	9	6	7	3
3	4	10	3	9
4	8	3	9	1
5	1	4	8	5
6	3	5	10	4
7	10	7	2	8
8	6	8	1	7
9	2	9	4	10
10	5	1	6	2

PART II

SELECTED RESULTS FROM AN EVALUATION OF THE DYNAMIC GENERAL EQUILIBRIUM MODEL (DGEM)

6. ESTABLISHING USER REQUIREMENTS FOR A MOBILIZATION APPLICATION[1]

The Dynamic General Equilibrium Model (DGEM) is an annual model for analyzing the structure and growth of the U.S. economy. DGEM incorporates a methodology for contingency planning so that quantitative analyses of the impact of economic policies and disruptions of the U.S. economy may be conducted. DGEM provides a detailed analysis of supply and demand factors for simulations up through the year 2000, as well as a framework for determining sector-specific demands and supplies and relating these developments to other sectors of the economy. DGEM was developed by Dale W. Jorgenson and Associates; it is an expanded version of the Long Term Interindustry Transactions Model[2] also known as the Hudson-Jorgenson Model.[3,4] The model was designed to deal with three major types of emergency situations: (1) energy-economic interactions associated with supply interruptions or strategic policies; (2) the economic impacts of a loss of resources due to an enemy attack on the United States with particular emphasis on which policies could stimulate recovery; and (3) the economic impacts of demand surges and resource constraints typical during a period of military mobilization. The focus of the material presented in Part II of this report is on a military mobilization application.

A military mobilization is a complex series of events which requires careful specification and in general, a variety of models and databases.[5] One of the key components of any such analysis is a macroeconomic model. The purpose of such models in a military mobilization is to specify how the transition from a peace-time to a war-time economy takes place. Once this information is available to the analyst, it becomes possible to design and evaluate alternative policies which should, at least in theory, stimulate or regulate certain sectors of the economy which could otherwise produce shortfalls or bottlenecks.

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[1] The material presented in this chapter has benefited substantially from information provided by: Prof. Ernst R. Berndt, Massachusetts Institute of Technology; Mr. David K. Henry, U. S. Department of Commerce; and Messrs. O. Cleveland Laird, E. Laurence Salkin, and Robert R. Wilson, Federal Emergency Management Agency.

[2] E.A. Hudson and D.W. Jorgenson, The Long Term Interindustry Transactions Model: A Simulation Model for Energy and Economic Analysis, Washington, DC: Federal Preparedness Agency, 1979.

[3] E.A. Hudson and D.W. Jorgenson, "U.S. Energy Policy and Economic Growth, 1975-2000," The Bell Journal of Economics and Management Science, Vol. 5, No. 2, Autumn 1974, pp. 461-514.

[4] E.A. Hudson and D.W. Jorgenson, "Assessment and Selection of Models for Energy and Economic Analysis," in Validation and Assessment Issues of Energy Models, S.I. Gass (Ed.), Gaithersburg, MD: National Bureau of Standards, NBS Special Publication 569, 1980, pp. 431-444.

[5] A multi-model approach to military mobilization is outlined in Appendix D.

Due to the importance of macroeconomic models in a mobilization, it is useful to establish a set of requirements which the model should possess. Four general requirements are presented in the text which follows. In Chapters 7 through 9, these requirements are expanded to incorporate the type of information described in Chapters 2 through 5. Chapter 10 concludes with an assessment of how well DGEM measures up to these requirements.

Requirement 1

The model must have documentation sufficient to enable an analyst to:

(a) set it up on the host system;
(b) execute a base-case simulation;
(c) interpret the results of the base-case simulation; and
(d) create, run, and interpret user-specified simulations.

Requirement 2

The structure of the model should be clearly documented. This requirement includes information on the model's:

(a) policy context;
(b) objectives;
(c) exogenous and endogenous variables;
(d) equation structure; and
(e) database(s).

To the extent feasible, the user should be assured that the forecast values of the base-case simulation have been compared to historically achieved values. Any major discrepancies should be documented and, if possible, explained.

Requirement 3

The model must be cross referenced to the National Income and Product Accounts (NIPA). This minimum requirement provides a set of control totals, which may be used to disaggregate the model's output to address sector specific issues. Furthermore, it is desirable for the model to provide information on those endogenous and exogenous variables likely to be of interest to decision makers. This information may be useful either in gaining insights regarding the "path" of the economy to a war-time footing or in preparing customized reports.

Requirement 4

The model must incorporate the following economic-technical attributes:

(a) the increasing importance of international trade over the past decade;
(b) the business cycle concept;
(c) the changing composition of the Gross National Product (GNP);
(d) the concepts of investment, capital services, depreciation, and emergency capacity;

(e) wage and price variables;
(f) both supply (e.g., capital and labor services available) and demand (e.g., military requirements) concepts;
(g) an explicit treatment of both fiscal and monetary policy;
(h) dynamic characteristics whereby production and consumption decisions in one period affect the economy in future periods; and
(i) bridges to or from key variables (e.g., from the NIPA components to specific sectors as defined by the Commerce Department's 4-digit Standard Industrial Classification (SIC)).

Items (a) through (i) are at the heart of most mobilization modeling problems. Consequently, it is essential that the model provide a means through which the user can address each item both individually and in combination. Only in this manner can the importance of individual items to the overall problem be measured. For example, a model which does not incorporate business cycles may be unable to measure the impact on wages and prices due to a mobilization which begins in a recession versus one which begins during a period of full employment. Similarly, defense expenditures are going to exert a different impact on certain sectors of the national economy than are other government expenditures. Finally, the model should provide sufficient sectoral detail to identify areas where in-depth studies may be worthwhile.

7. THE DGEM ANALYSIS FRAMEWORK

This chapter addresses the issues discussed in Chapters 2 and 3. Background information is presented first; this information serves to define the motivation for the model and its theoretical underpinnings. The focus is then shifted to the DGEM software, including: (1) a review of the DGEM source code; (2) the implementation of the model on the NBS computer system; and (3) enhancements which were made to the basic code. The section concludes with a report on NBS' experiences, as well as those of several other Federal agencies, who used the model to reproduce the base-case simulation and then performed certain mobilization-oriented studies.

7.1 THE DGEM DOCUMENTATION

The material which follows is based on a thorough review of the DGEM documentation reports. In some cases, the material presented incorporates information provided to the NBS staff by the model developers. Most of this information was prompted by the need for NBS to bring the DGEM code into compliance with the ANSI X3.9-1978 standard for FORTRAN 77. Although this information delves deeper into the documentation than would be required for an analyst to understand and use the model, it helps to integrate material from several different documentation reports into an overall picture of how the model operates.

From a review of the documentation, it is clear that much care went into the design, development and testing of the model. The documentation is quite complete and should be sufficient for an analyst to setup and run the model on the host system and interpret its output.

The documentation reports were prepared in two stages. The first stage consists of a set of reports on:

(1) household[1] and producer[2] behavior;
(2) comparisons of the DGEM predictions against realized values up through 1974;[3] and
(3) results from a series of tests on the convergence properties of the model for extreme changes in certain key variables.[4]

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[1] The 36 Sector Model of Household Behavior, Lexington, MA: Data Resources, Inc., 1979.

[2] The 36 Sector Model of Producer Behavior, Lexington, MA: Data Resources, Inc., 1979.

[3] Simulations of the 36 DGEM Over the Historical Period, Lexington, MA: Data Resources, Inc., 1980.

[4] Test and Sensitivity Simulations of the 36 Sector Dynamic General Equilibrium Model, Lexington, MA: Data Resources, Inc., 1980.

The second stage consists of a set of reports giving:

(1) explicit instructions for applying the model to a wide variety of emergency situations;[1]

(2) descriptions of key variables, comparisons of how the model performed outside the estimation period, and details of the base-case projection through the year 2000;[2] and

(3) a mathematical description of the model, including key equations, and the solution algorithm.[3]

The approach used in DGEM is based on the application of econometric modeling to input-output analysis. Where input-output analysis assumes fixed input-output coefficients at any point in time, DGEM provides for flexible input-output coefficients induced by price variations in primary inputs which are associated with economic policies or anticipated contingencies. The complete model consists of an inter-industry model incorporating the flexible input-output methodology and a macroeconometric model that integrates demand and supply conditions for consumption, investment, capital and labor.

The macroeconometric model divides economic activity into four types of goods and services: the output of consumption and investment goods; and the inputs of capital and labor. A production function relates the output of consumption and investment goods to the inputs of capital and labor services, for a given level of technical efficiency.

The inter-industry model determines inter-industry transactions for 36 domestic sectors (see Table 7.1), the demand for primary inputs, the allocation of GNP as final demand among the sectors, and the total sector outputs. The technology of each producing sector is represented by a price possibility frontier that determines the supply price of output as a function of the prices of primary and intermediate inputs and the level of technical efficiency.

Each of the 36 sectors in the domestic economy is represented by a submodel of producer behavior. These submodels are based on the translog price possibility frontier. This frontier is a function relating the price of output charged by a sector to the prices that the sector pays for its inputs. Output price equals average cost, with profit, in the form of return to capital, being included in this cost. Also, technical change is included in the price frontiers.

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[1] R.J. Goettle and E.A. Hudson, User's Guide to the 36 DGEM Simulation Model, Cambridge, MA: Dale Jorgenson and Associates, 1984.

[2] R.J. Goettle and E.A. Hudson, Final Report on the Dynamic General Equilibrium Model, Cambridge, MA: Dale Jorgenson and Associates, 1984.

[3] R.J. Goettle and E.A. Hudson, 36 DGEM: The Dynamic General Equilibrium Simulation Model, Cambridge, MA: Dale Jorgenson and Associates, 1984.

The household sector is also explicitly analyzed, not only in terms of its demand for the output of the producing sectors but also in terms of the supply of labor and the volume of saving. Part of the model is organized within an interindustry transactions framework. This permits balance and consistency between input and output patterns to be achieved over all intermediate and final goods markets. Another part of the model covers the supply of primary inputs, in particular of capital and labor, the demand for these inputs and the adjustment of activity patterns so that the input markets are in balance. The model also covers the growth of the economy over time with explicit attention given to savings and investment mechanisms and expansion of productive capacities through increases in capital and labor input and improvements in technical efficiencies.

The analytical framework in DGEM incorporates several key factors. The consistency of the framework ensures that the quantity and the value of flows in each market in the economy are simultaneously in balance. Both price and quantity aspects of economic activity are explicitly included in the model. Behavior by producers and consumers is considered in both price and quantity terms. For producers, the formation of output prices is considered as well as the selection of those input patterns that are appropriate in the face of these prevailing input and output prices (i.e., the determination of the input-output coefficients for each producer as a function of technological information and of prevailing prices). For the household sector, prices enter the determination of labor supply, of total consumption expenditure, and of saving. In addition, the quantities of household demands for produced goods and services are functions of preference parameters and the prevailing price.

The flow of inputs to and outputs from production is handled within an interindustry transaction framework. In this framework the transactions are organized in a matrix with each column representing inputs to an industry and each row representing sales or output from an industry. Each row corresponds to supply from a sector; each column represents purchases by a sector. There are 36 producing sectors. There are three further sources of supply: (1) capital services; (2) labor services; and (3) imports. Also, there are four more purchasing sectors, the final demand activities. These are: (1) personal consumption; (2) investment; (3) government purchases; and (4) exports.

To summarize, DGEM is comprised of several components.

1. Submodels of producer behavior, one for each of the 36 domestic producing sectors.
2. A model of consumer behavior.
3. Balance equations covering physical flows through the interindustry system equating demand and supply quantities of each good or service transacted.
4. Market balance equations equating value of expenditure and receipts for each good or service transacted.
5. Financial identities aggregating value flows into aggregate income, financial and economic accounts.
6. Government and rest of the world accounts.

Table 7.1 The DGEM Sectoring Scheme

Sector Number	Sector Name
1	Agriculture, Forestry and Fisheries
2	Metal Mining
3	Coal Mining
4	Crude Petroleum and Natural Gas
5	Nonmetallic Mining and Quarrying, except Fuel
6	Construction
7	Food and Kindred Products
8	Tobacco Manufactures
9	Textile Mill Products
10	Apparel and Other Fabricated Textile Products
11	Lumber and Wood Products
12	Furniture and Fixtures
13	Paper and Allied Products
14	Printing, Publishing and Allied Industries
15	Chemicals and Allied Products
16	Petroleum Refining
17	Rubber and Miscellaneous Plastic Products
18	Leather and Leather Products
19	Stone, Clay, and Glass Products
20	Primary Metal Industries
21	Fabricated Metal Products
22	Machinery, except Electrical
23	Electrical Machinery

Table 7.1 The DGEM Sectoring Scheme (continued)

Sector Number	Sector Name
24	Motor Vehicles and Motor Vehicles Equipment
25	Transportation Equipment & Ordnance, except Motor Vehicles
26	Instruments
27	Miscellaneous Manufacturing Industries
28	Transportation
29	Communications
30	Electric Utilities (including Federal, state, and local)
31	Gas Utilities
32	Trade
33	Finance, Insurance, and Real Estate
34	Services (including water and sanitary services)
35	Government Enterprises (excluding electric utilities)
36	Miscellaneous

7.2 SOFTWARE CONSIDERATIONS

The current version of DGEM is written in FORTRAN 77 and designed for execution on any mainframe or mini which supports the ANSI X3.9-1978 standard for FORTRAN. During the review of the source code, which was provided to NBS by FEMA, it became obvious that several modifications would be required if the model were to run on equipment other than the UNIVAC 1100 series of computers, the original target machine configuration. The review of the source code did, however, demonstrate that the description of the mathematical model given in the 36 DGEM: The Dynamic General Equilibrium Simulation Model report is an adequate description of the operational model.

7.2.1 Code Review and Modification

The discussion which follows first focuses on a brief description of the solution procedure. This discussion parallels that given in the 36 DGEM: The Dynamic General Equilibrium Simulation Model report. Emphasis is then placed on documenting the changes in the DGEM source code resulting from its implementation on selected mini and mainframe computer systems. A one page description of each subroutine, which identifies specific code modifications, is given in Appendix F.

The basic approach of the DGEM model is to generate a numerical solution for a set of simultaneous equations. The simulation program provides a framework for this solution and for the handling of the large amounts of data and information generated. The components of the program are subroutines that handle data input, subroutines that incorporate the equations of the model, procedures for numerical solution of equation systems, and subroutines for the handling of solution information. These are organized into a consistent framework by the MAIN program.

The logical sequence of the simulation is as follows. First, control information such as the simulation period and the nature of any alterations to the system is inserted. Then, the database is assembled from the data file. This database comprises the values of the endogenous and exogenous variables over the simulation period and the values of the coefficients or parameters of the model system.[1] Any user-specified changes in data or assumptions are also introduced. Next, the equations of the model are introduced. Then, sequentially, for each year of the simulation period, the equation system is solved, given the values of the exogenous variables and the coefficients. For each year's solution, the numerical values of the exogenous variables, the lagged endogenous variables, and the coefficients are inserted into the equations. This generates a system of N equations involving N variables, the N endogenous variables. A numerical solution algorithm is then used to ascertain these solution values for the endogenous variables. The values of the endogenous variables are stored for use in the next year's simulation, as lagged endogenous variables. Also, the

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[1] The data file, from which the database for the simulation is developed, contains information covering the years 1958 through 2000. The post 1982 values in the data file are projections, based on data available in 1983, which include: (1) trends in real economic growth and inflation; (2) the business cycle; (3) aggregate sources of growth; (4) trends in final demand; (5) energy use; and (6) industry developments.

solution values are saved for display at the conclusion of the simulation. This solution sequence is then repeated for each year of the simulation period. Finally, the solution information for the entire simulation period is displayed in the form and for those variables requested by the user.

The structure of the DGEM simulation program is illustrated in Figure 6.1. Figure 6.1 shows the principal information flows in the program and indicates, in capitals, the principal subroutines involved at each step. The program first collects control information through subroutines CHROPT and CNTRLR. These introduce run control options,[1] the initial and final simulation years, whether the simulation is static or dynamic,[2] the number and specification of endogenous variable constraints to be imposed on the model, the number and specification of data changes to be introduced, and a series of print controls. Subroutine DATA is then called to read the data for the endogenous variables, the exogenous variables, the coefficients, the values for each constraint variable, and any adjustments in the exogenous variables. The values of the lagged endogenous variables for this simulation year are then assembled by subroutine SAVLAG, drawing on the previous year's data values (for the first year) of the endogenous variables. Under some output specifications, actual values of user-selected variables will be saved here so that they can be compared, after solution, with the simulated values of these variables; subroutine SAVOUT is concerned with this data storage. At this point, all the information is in place for the initiation of the simulation. As the model equations are solved numerically, an initial guess of the values of the endogenous variables is required. Specifically, only N(N≥40) endogenous variables are solved for numerically in the reduced dimension system, so initial guesses on these N basis variables are required.[3] These guesses are selected by subroutine GUESS, drawing on the actual values of the endogenous variables. The solution procedure is now invoked; this is handled by subroutine NEWTM, which begins at statement label C. The data (exogenous variables, lagged endogenous variables, and coefficients) are inserted into the model equations, contained in subroutines FCR, FCRVAL, SHPRA, FCRA, FCRB, and SHPRB. The equations are evaluated given the current guess of the values of the endogenous variables.

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[1] Examples of run control options are: (I) output the National Income and Product Accounts for each year; (J) print a table of energy aggregates for each year; (M) create a new data file; and (R) suppress the standard output whenever reports on special variables are desired.

[2] In a dynamic simulation the solution values for one year form the initial conditions for the following year.

3 The value of N is at least 40. In this case, the first variable is IVT, the next 36 variables correspond to the vector PFM(i), the last three variables are PKD, PLM, and RNW, respectively. In cases where N is greater than 40, the first 40 variables are as defined above and the basis includes one additional variable for each equality constraint. The variable corresponding to each equation is the instrument nominated by the user.

Figure 7.1 Flowchart of the DGEM Computer Program

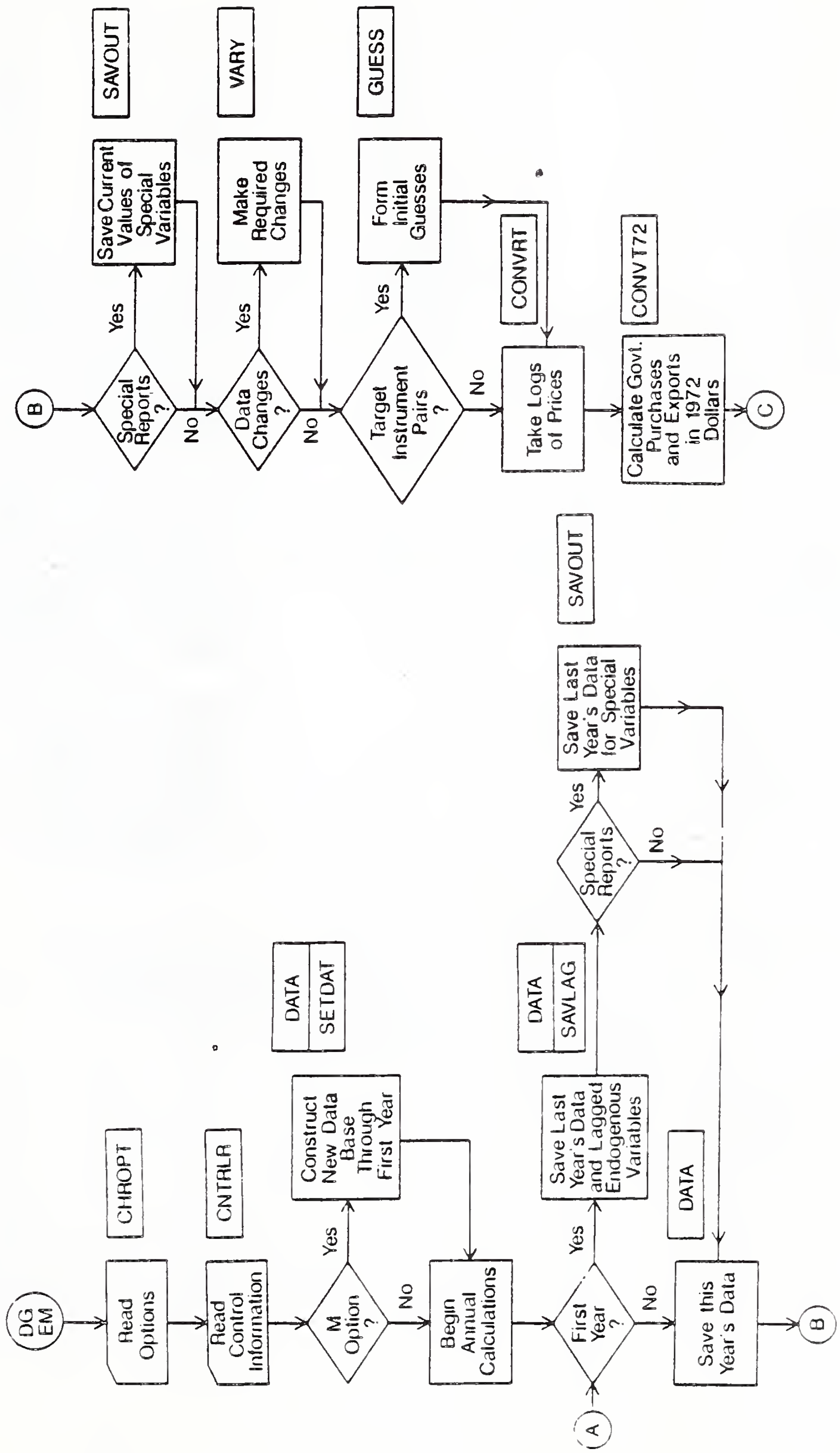


Figure 7.1 Flowchart of the DGEM Computer Progarm (continued)

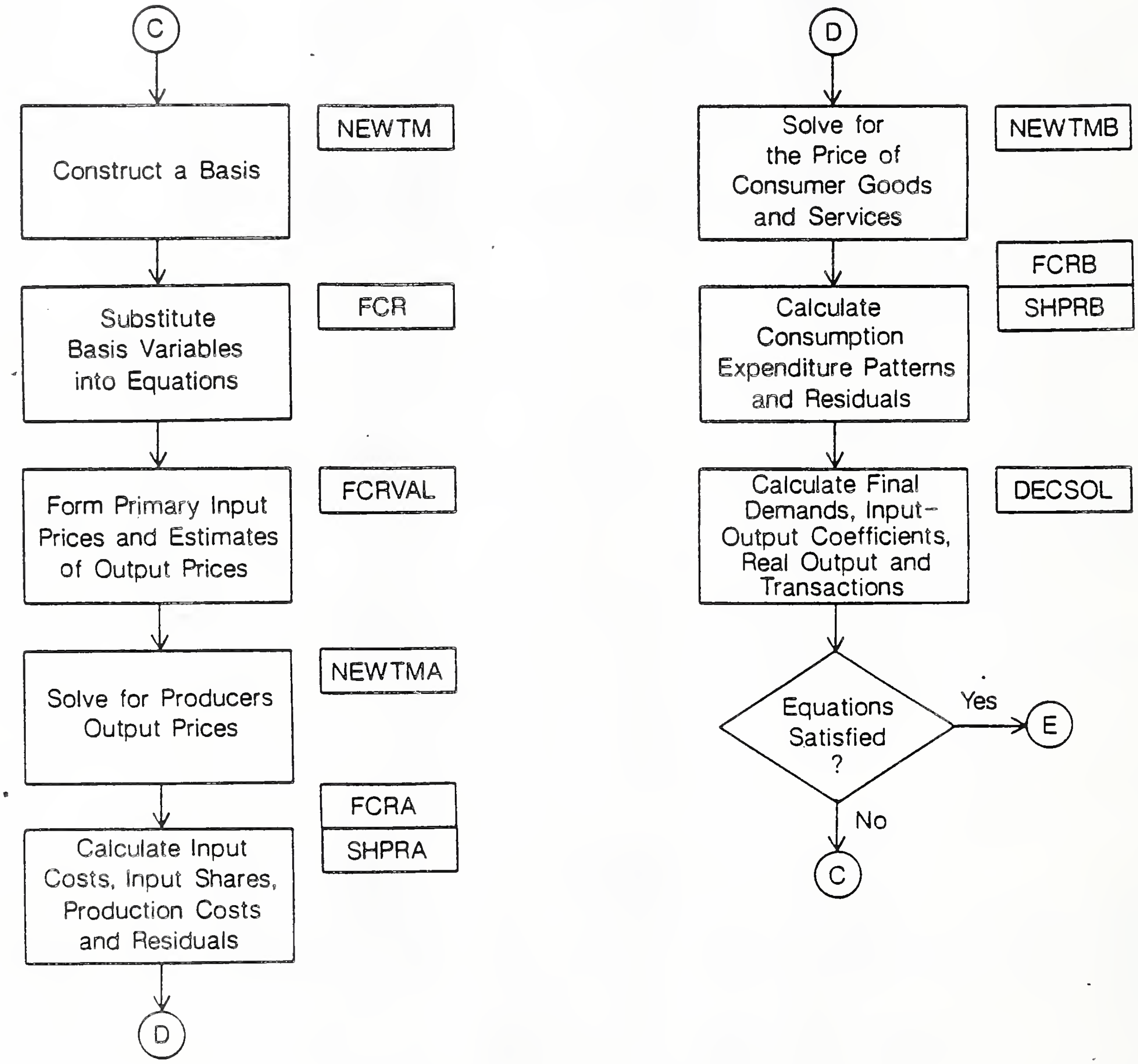
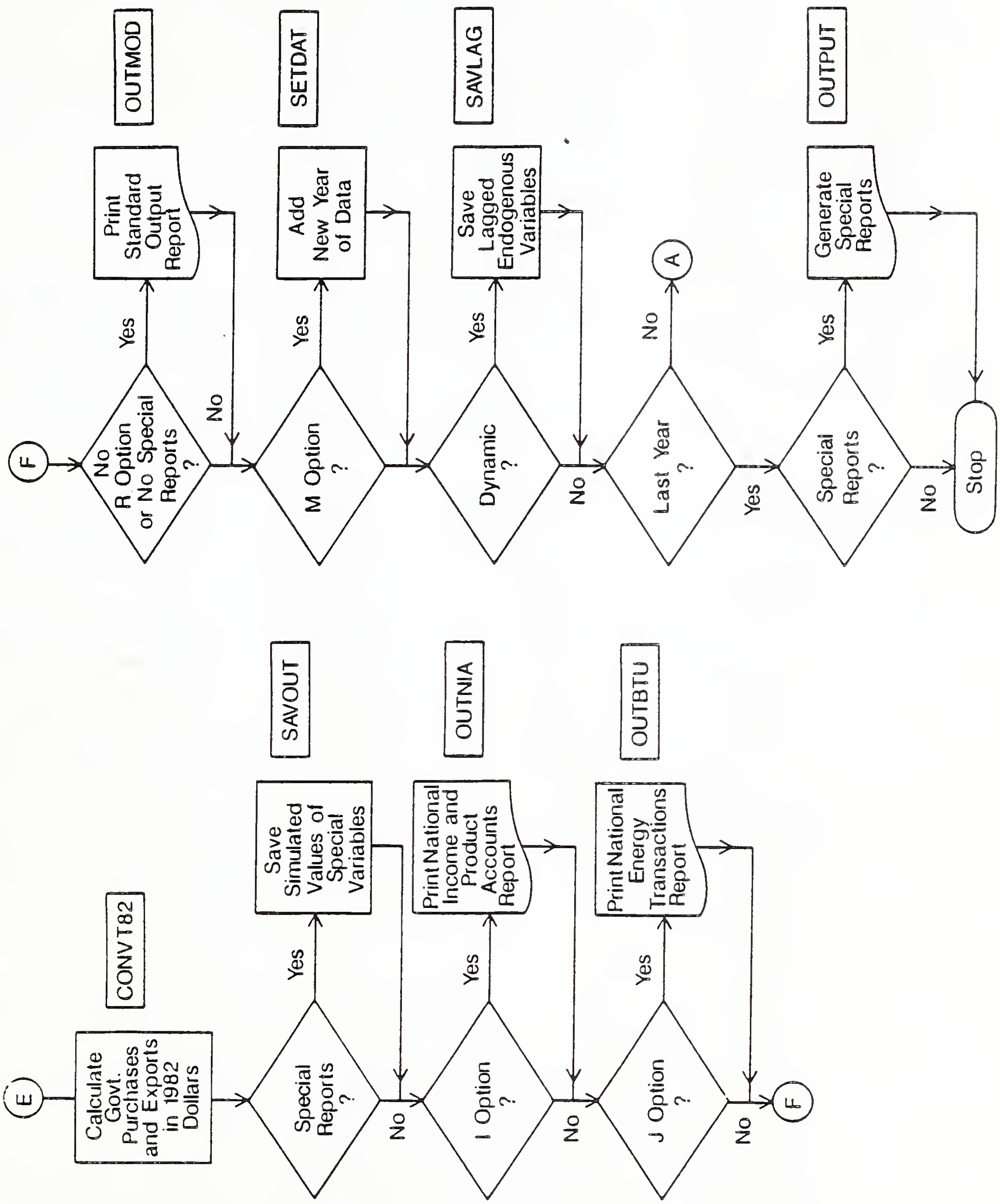


Figure 7.1 Flowchart of the DGEM Computer Program (continued)



This evaluation is partly a matter of recursive equation solution but also involves the numerical solution of three blocks of equations (i.e., there are three separate numerical solutions within the outside numerical solution loop). One block is solved for the output prices using a Newton's method procedure in NEWTMA that, in turn, employs FCRA and SHPRA; the next block involves solving for the pattern of household sector purchases which uses subroutines NEWTMB, FCRB, and SHPRB; and the third block involves the interindustry transactions balances and is solved by the linear equation solver DECSOL. If the equations hold exactly (i.e., the N residuals corresponding to the basis variables are simultaneously zero) the current endogenous variable values are solution values and no further processing is required (i.e., passes out through statement label E). If the residuals are not zero, the outside loop Newton's method algorithm commences a systematic adjustment of their values (i.e, returns to statement label C). After each adjustment, the entire model is re-evaluated and the residuals computed. When the residuals are simultaneously zero, model solution has been achieved and the adjustment procedure is halted. The solved values are saved, by SAVLAG, to provide the lagged values for the next year's simulation. Also, the solved values are stored, for display or analysis after the simulation has been completed. Subroutine SAVOUT saves specific information for OUTPUT; OUTMOD organizes and prints blocks of variables. The program now moves to the next year and repeats the solution process. This continues until the system has been solved for every year of the specified simulation period. Finally, the output information requested by the user is displayed from subroutine OUTPUT.

The method of evaluating the equations of DGEM is itself complicated. This solution is handled by the Newton's method procedure in subroutine NEWTM which calls subroutine FCR to evaluate the equations. The equations are set up as a sequence of equation blocks that can be solved conditionally on the values of N basis variables. The purpose of FCR is to evaluate N residual equations corresponding to these basis variables; NEWTM adjusts the values of these variables until the residuals are simultaneously zero. Within FCR, the entire system of equations must be evaluated. FCR inserts the values of the basis variables into these variables by name then calls subroutine FCRVAL. FCRVAL calculates the primary input prices and makes initial guesses on the output prices before calling NEWTMA to solve numerically for the output prices. NEWTMA calls subroutine FCRA (which, in turn, uses SHPRA) to calculate input costs, input shares, production costs and, from these, the residuals for the output prices for flexible share sectors. It also calculates average price residual for fixed coefficient sector (i.e., sector 36). Once the output prices have been determined, FCRVAL proceeds to construct initial estimates of the expenditure weighted average price facing households, PCC. NEWTMB is then used to numerically solve for this consumption price. The equations used in this solution are in FCRB and SHPRB and cover the determination of consumption expenditure patterns. With these consumption prices and consumption patterns, FCRVAL proceeds to calculate all production and final demand prices, to find all final demands, and to compute the input-output coefficients. Next, the input-output system is solved numerically using DECSOL, a linear equation solver. From the resulting sectoral outputs the entire matrix of real transactions is calculated. Next, the financial, government and foreign trade variables are calculated. At this point, all equations and variables in the model have been evaluated except for the N equations corresponding to the basis variables. The program now returns to FCR where these N equations are evaluated, yielding the residuals used by NEWTM in solving for the N basis variables.

Shortly after our initial review of the DGEM documentation and source code was completed, NBS installed a new computer system. The new system consists of a CDC Cyber 205 (622 series) supercomputer coupled with a CDC Cyber 180/855 mainframe computer. The Cyber 855 is used as the front-end system for the supercomputer. For a brief period during the summer of 1985, both the original NBS Sperry UNIVAC 1100/82 system and the new Cyber 205-855 were operating concurrently. This enabled the NBS team to perform extensive testing and code revisions simultaneously on both machines. Side-by-side comparisons of the model's output were then performed to catch errors introduced by the code revisions or to isolate second-order effects. This approach was taken to ensure that changes in the model's logic were not inadvertently introduced into the source code. Copies of the revised source code and a sequential version of the data file were provided to the developers for their review. Several enhancements were subsequently incorporated by the developers to facilitate the use of the Mobilization TUTOR described in Section 7.2.2. The discussion which follows incorporates these enhancements.

The revised code now satisfies the ANSI X3.9-1978 standard for FORTRAN and is operational on the NBS Cyber 205-855 system and the Center for Computing and Applied Mathematics VAX/VMS 11-785 minicomputer. Major revisions to the DGEM source code were of three types. All three types of revisions were due to the use of Sperry UNIVAC extensions to the FORTRAN standard. The first set of code revisions is related to the use of INCLUDE statements throughout the model. The second set of revisions involved four blocks of subroutines; these blocks are associated with the following subroutines: (1) DECSOL; (2) FCRA; (3) FCRB; and (4) GETOUT. The third set of revisions involved character string manipulations, most notably within the original GETOUT block of subroutines referred to hereafter as the "parser." Minor revisions to the DGEM source code included: (1) file definition statements; (2) the initialization of certain key variables within subroutines; and (3) settings for the variables used to test for convergence. Brief descriptions of each type of revision are given in the text which follows. Subroutine-by-subroutine descriptions of code revisions are given in Appendix F.

The INCLUDE statement is a Sperry UNIVAC extension to the ANSI X3.9-1978 standard for FORTRAN; it inserts an externally defined set of FORTRAN statements into the program being compiled. The Sperry UNIVAC Procedure Definition Processor (PDP) is used to create a FORTRAN PROC. This is the set of FORTRAN statements which can be inserted into the source language with an INCLUDE statement. The PDP accepts the source language statements defining FORTRAN procedures and builds an element in the user-defined program file. By using INCLUDE statements, these procedures may be referenced subsequently in a compilation without redefinition. This approach saves both time in recompilation and space in the program listing.

A normal application for INCLUDE procedures is one or more INCLUDE elements containing a set of data declarations shared between different portions of a larger user program. In the case of DGEM, INCLUDE statements were used to refer to named COMMON blocks and the PARAMETER block. This convention prompted a replacement of the INCLUDE statements with explicit COMMON block statements and, where appropriate, with the PARAMETER block statements. In addition, it was necessary to replace the FORTRAN procedures with a BLOCK DATA subprogram. Under the ANSI X3.9-1978 standard, BLOCK DATA subprograms are used to specify parameters and to provide initial values for variables and elements in named COMMON blocks. Brief descriptions of all DGEM named COMMON blocks are given in Table 7.2.

A subprogram is a program unit that has a FUNCTION, SUBROUTINE, or BLOCK DATA statement as its first statement. A subprogram whose first statement is a SUBROUTINE statement is called a subroutine subprogram.

Under the Sperry UNIVAC implementation of FORTRAN, a subroutine subprogram may be referred to either as external or internal. A subroutine is external if it appears as the first program unit in the source input, or its SUBROUTINE statement is immediately proceeded by an END statement. Otherwise the subroutine is internal. The Sperry UNIVAC implementation of FORTRAN permits an external subroutine subprogram to contain several internal subroutines (i.e., several SUBROUTINE statements). As indicated earlier, there were four cases in which an external subroutine subprogram contained more than one SUBROUTINE statement.[1]

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[1] In the original source code, subroutine OUTPUT contained two FUNCTION statements. Subroutine OUTPUT was revised in the same way as subroutines DECSOL, FCRA, FCRB, and GETOUT (see the text which follows). However, the changes to subroutine OUTPUT were relatively straight forward.

Table 7.2 DGEM COMMON Blocks

Name	Purpose
B	Variable names and coefficient names
CHRSET[a]	Host's FORTRAN character set
CNTRL	Control Parameters
COEFF	Coefficients
DIMSIZ[a]	Dimensions for special output variables
ENDOG	Endogenous variables
EXOG	Exogenous variables
ICOB	Cobb-Douglas specifications
LAG	Lagged variables
OPT[b]	Defines DEBUG
OPTN[a]	Defines DEBUG
OTPTNM	Information on special
OUTPTA	variables for which
OUTPTB	the user wants reports
TARINF	Information on user-controlled variables
TIERH	Indices for the household model
TIERP	Indices for the producer models

[a] New COMMON block

[b] No longer used

Under the Sperry UNIVAC implementation, entities that may be referenced from both external and internal program units are referred to as global. Entities which may be referenced only within a particular internal subprogram are referred to as local (i.e., local to that subprogram). Entities used in an external program unit can not be referenced by another external program unit unless they are in COMMON blocks or passed as arguments. Variables, arrays, parameter variables, and so forth, which are declared or used in an external program unit can be referenced by any of its internal subprograms. Consequently, the names of certain entities need not be used as arguments in calling an internal subroutine.

The code revisions prompted by the Sperry UNIVAC extensions to the FORTRAN standard were of two basic types. First, each subroutine was made external. This was done by ensuring that an END statement was the last line of each subroutine. Second, the calling sequence for each subroutine which was formerly internal now includes, as explicit arguments, the names of entities which are referenced within it and which were previously local. For example, the calling sequence for subroutine OFFSET within subroutine GETOUT was changed from

```
CALL OFFSET(IVAR)
```

to

```
CALL OFFSET(IVAR,SUB1,SUB2,SUB3,SUB4,POINT,INREC,KEYVAR,LOCVAR)
```

because variables SUB1 through LOCVAR were previously treated as local variables.

The purpose of the parser is to read the run control information. This includes the specification of User/DEBUG options (see Table 7.3), the first and last years of the simulation, whether the simulation is static or dynamic and the numbers of target instrument pairs, data changes and outputs. The names and values of the variables are also read.

The need to revise the parser was due to the use of word-length dependent software designed for execution on Sperry UNIVAC equipment. This software was very flexible in that it enabled the analyst to operate on bit strings. Unfortunately, the Sperry UNIVAC operates on a 36-bit word. Thus, word bytes and OCTAL field codes which operate on Sperry UNIVAC equipment will either not work or may produce misleading results on other machines. For example, the FLD function used in subroutine PACK operates on the Fieldata code set rather than the ASCII code set. Although all Fieldata characters have corresponding representations in ASCII, characters are four to a word rather than six and will have different internal representations. A similar problem results from using INTEGER declarations to store 6-character strings or multiples thereof.

Table 7.3 User/DEBUG Options for DGEM

OPTION	FUNCTION
B	Suppress all Newton's method output.
C	In subroutine FCRVAL, suppress the calls to the FCRA and FCRB subroutines (i.e., compute only those variables listed in FCRVAL).
D	Suppress all lagged endogenous variable output.
E	Call subroutine OUTMOD after the first time through FCRVAL.
F	List the residuals from NEWTMA, the numerical solution for PO.
G	List the residuals and the expenditure share from NEWTMB, the numerical solution for PCC.
H	Compute only the financial variables in subroutine FCRVAL, omitting all other equations and suppressing the calls to the FCRA and FCRB subroutines.
I	Output National Income and Product Accounts for each year.
J	Print table of energy aggregates for each year.
K	List PO every time subroutine FCRVAL is called.
L	List household prices every time through subroutine FCRVAL.
M	Overwrite the file database with the database created in this run. (Use this option with caution -- the previous database will be lost.)
R	Suppress standard output whenever NUMOUT is greater than zero.
S	Print the interindustry transaction results (specifically, the P, XT, YF, and ZX matrices in constant and current dollars).
T	Print the input-output coefficients and import shares.
U	Print all endogenous variables.
V	Print all exogenous and lagged variables.
W	Print all coefficients.
X	Diagnostic messages in subroutine GETOUT.
Z	Writes the simulated values of NUMOUT variables to logical unit 12 (the values are written in card image format).

To get around the first problem, a new subroutine, CHROPT, was developed. Subroutine CHROPT initializes an array, FLDTA, in terms of the host installation's FORTRAN character set. To get around the second problem, an explicit CHARACTER statement is used rather than word bytes (i.e., INTEGER declarations).

The minor revisions to the DGEM source code will now be described. The DGEM data file consists of 19,327 entries for each of 43 years (i.e., 1958 through the year 2000). Consequently, it was necessary to properly define the file so that individual entries could be retrieved and/or stored. This was accomplished through the use of OPEN statements in the MAIN program for the Cyber version and in the DATA and SETDAT subroutines for the VAX version. One reason for the difference in where the OPEN statements are placed has to do with whether the operating system can handle large direct-access files.

Several subroutines in the original DGEM source code used DATA statements to initialize key variables. For example, in subroutine NIPABR the variables TEMPX and TEMPM are used to calculate for each year of the simulation the value of exports and imports, respectively. If the values are initially set to zero with a DATA statement, then with each subsequent call to subroutine NIPABR they will contain the cummulative values for all previous years of exports and imports. Consequently, it was necessary to replace all such DATA statements with explicit statements, such as

```
TEMPX=0.0

TEMPM=0.0 ,
```

in each of the affected subroutines.

Based on discussions with the model developers, it was decided to change the settings for the variables used to test for convergence. These changes were all within the Newton's method subroutines (i.e., NEWTM, NEWTMA, NEWTMB); in each case the stringency of the convergence criterion was relaxed somewhat. The effect of these changes was to significantly speed up convergence, because fewer iterations were required, without significantly changing the precision of the solution values.

Several other changes which should be noted involve the insertion of explicit COMMENT statements and the addition of two new subroutines. The first change was performed to replace within line comments with full line comments. Where appropriate, additional comment lines were inserted to provide greater detail on what calculations were being performed. The two new subroutines were required to accommodate the new capabilities provided through the use of the Mobilization TUTOR. The two new subroutines are CONVT72 and CONVT82, which convert government purchases and exports to 1972 and 1982 dollars, respectively.

7.2.2 The Mobilization TUTOR

In an actual application, it is necessary for the analyst to first construct a runstream file. This file defines the years of the simulation, the variables and their values which require modification, and the types of reports desired.

The runstream file consists of two parts. The first is a set of job control language to set up the file assignments and initiate execution. The second is a set of control instructions.

The control instructions consist of two parts. The first part of the control instructions contains the following information:

1. The options selected by the analyst for specialized outputs and file manipulations;

2. The period of the simulation;

3. Whether the simulation is static or dynamic;

4. The number of variables to be scaled under instructions from the analyst;

5. The number of variables to be set to specified values by the analyst;

6. The number of endogenous variable equality constraints (i.e., target/instrument pairs) that the analyst is going to specify; and

7. The number of reports for variables that the analyst is going to specify.

The second part of the control instructions contains the following information:

1. Names of exogenous variables or coefficients to be scaled;

2. Scale factors for each of the named exogenous variables or coefficients;

3. Names of exogenous variables or coefficients to be set;

4. Numerical values, for each year of the simulations, for each of the named exogenous variables or coefficients to be set equal to;

5. Pairs of variable names, one pair for each endogenous variable to be targeted;

6. Numerical values for the targets, for each year of the simulations, for each of the endogenous variables to be constrained; and

7. Names of variables for which detailed reports are to be generated.

The previous discussion provides an indication of both the complexities and subtleties inherent in the construction of the runstream file. Consequently, in order to promote the use of DGEM by a wide class of analysts, an on-line TUTOR was developed.

The TUTOR, through a nested set of menus, prompts the analyst to provide information which captures the economic issues inherent in major application areas such as military mobilization. Furthermore, the TUTOR provides direct, on-line access to the data file. The analyst in constructing the runstream can therefore examine the base-case values (i.e., both the realized and projected) contained in the data file to provide guidance in selecting the values of key variables for the event to be analyzed. In cases where endogenous variables are to be set to a specified level (i.e., targeted), the TUTOR recommends to the analyst one or more instruments which will affect the value of the targeted variable. The TUTOR stores all intermediate results in a scratch file. Once the analyst is satisfied that answers to all of the major questions have been provided, the TUTOR constructs and formats a runstream file. The TUTOR-generated runstream file can be used to execute DGEM or further refined by the analyst.

Initially, the TUTOR presents the analyst with several areas or options each characterizing some aspect of the event. This is the start of the detailed specification of the event. Indicators of the industry, structure and duration of the event (e.g., military mobilization) are selected or specified here. Policy responses are also selected here, as are reports on the economic effects of the event.

The definition of the event is accomplished through a tree structure. Each area of economic or policy specification leads, according to which instruction the analyst provides, to more detailed areas. In this way, the analyst can provide a comprehensive definition of the event in areas of greatest concern, while providing only the most general definition in other areas. In other words, the analyst can control the definition of the event to be analyzed.

There are four broad areas that provide the starting points for the definition of the event.

1. Defense and other government purchases.

2. Resources and foreign trade.

3. Government policies.

4. Reports.

Defense and Other Government Purchases

Government purchases are separated into three types of government activity: Federal defense; Federal nondefense; and state and local government. In turn, each type of government activity involves purchases, spread over a number of supplying industries. For Federal defense purchases, a rudimentary bridge table, which distributes defense purchases from the 55 DoD procurement categories to the 36 producing sectors, is included in the TUTOR. The analyst can therefore control defense spending in a variety of ways within this structure. Overall levels of defense spending can be altered, leaving the composition unchanged, or the composition and level can be changed. Specific defense procurement categories can be altered, year by year. Federal nondefense purchases and state and local government purchases are spread over the 36 producing sectors. Federal nondefense purchases can also be altered in total or industry by industry. State and local purchases can be altered in total, although the composition remains the same.

Resources and Foreign Trade

This area covers critical inputs to production. Generally, labor and capital are the most important inputs. Labor covers overall population and labor conditions as well as the availability of labor to specific industries. Similarly, overall capital stock and effective capital input are covered, as well as capital availability to specific industries. Foreign trade covers imports and exports, each of which can be affected by an event.

A detailed list of indicators describing population and labor input is provided should the analyst choose to go through the labor branches of the specification tree. Initial population, population growth rates, labor force participation patterns, work hours and vacation patterns, and labor efficiency are all included. Also, the analyst can specify how labor is used (i.e., the allocation of labor between industries and the amount of labor available to particular industries).

Similar possibilities are included for capital. The initial operational capital stock, the efficiency or intensity of use of the capital stock, and depreciation rates describe the general features of capital. Finally, capital availability by industry can be specified. For example, if it were known that certain industries had capacity reserves which could be called upon in times of emergency, these net additions to the capital stock could be modeled explicitly by the analyst.

Imports can be specified industry by industry and the analyst also has the choice of tariffs or quantitative controls for limiting imports. Exports can be altered industry by industry or the overall volume of exports can be changed, keeping the composition unaltered. Also, there are considerations for the balance of trade. This can be unconstrained or it can be subject to limits, reflecting the constraints that usually exist on the balance of trade.

Government Policies

A wide range of policy measures are available to the U.S. government for use during or after a major event such as military mobilization. Some of these policies involve purchases of goods and services; some policies control the allocation and use of available resources, in particular labor and capital; some policies control production activities, the level of operation of specific industries; some policies involve monetary and credit conditions, affecting the level of borrowing and spending; and some policies affect fiscal conditions, such as government spending, taxation, deficits and borrowing. These types of policies are included and can be specified by the analyst.

For example, fiscal policy involves government revenues and expenditures, and their difference, the government deficit. Government revenues, primarily taxes, reduce the level of private disposable income and spending. Government purchases are themselves an element of spending and directly add to private spending in demand for goods and services. The government deficit affects the capital markets, since the deficit is financed by government borrowing. The larger the deficit, the more private capital is preempted (i.e., crowded out), reducing the availability of funds for private spending, and showing up particularly in its effect on private investment. Each of these policy measures is available to the government and each can be adjusted by the analyst in designing the analysis of the event.

Reports

The analyst can specify what information to retrieve from the simulation. While all of the previous considerations referred to defining the event to be investigated, this area covers the data to be reported after the simulation has been completed. A range of reports is available and the analyst can select from these to tailor the computer reports to the types of indicators and analysis desired.

The first set of reports covers the Gross National Product accounts. These can be reported in current dollars, in constant dollars, or in terms of price indices. They can also be reported in terms of different types of spending (i.e., consumption, investment, government, exports and imports). At the aggregate level, the Gross National Product indicators summarize spending, production and prices.

Government purchases are covered in the next set of reports. Then, there are reports on labor. These cover population, labor supply, labor prices (or compensation rates), and labor input by industry. Similarly, for capital, there are reports on capital stock, capital input, rates of return and capital input by industry. At the industry level, there are reports on production levels and on market demands. Prices can be reported at the overall level, by good or service, and by industry. Interest rates can also be requested. All of these choices are menu-driven. In addition, there is opportunity for the analyst to request a report on any variable in the model by specifying the name of the variable.

7.3 DGEM FROM THE USER'S POINT OF VIEW

Over the past year, DGEM has been used extensively by the NBS project team. The model is also currently being used by at least five Federal agencies and four non-Federal installations. Whereas the work carried out at NBS has encompassed a wide variety of modeling techniques, the activities of the other users have had a narrower focus. In particular, much of the non-NBS work has focused on gaining a better understanding of the model through interactive sessions on the TUTOR.

The installations to which NBS has supplied copies of the DGEM software system[1] include:

(1) Economic Research Service
U.S. Department of Agriculture;

(2) Office of Business Analysis
U.S. Department of Commerce;

(3) Office of Industrial Base Assessment
U.S. Department of Defense;

(4) Office of Industrial Mobilization Programs
General Research Corporation;

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1 Whenever the term DGEM software system is used, it is meant to include the source code for both DGEM and the TUTOR, the DGEM database, and a set of one or more test problems and solutions. Software documentation is also provided.

(5) Systems Analysis Department
Swedish National Defense Research Institute;

(6) Department of Operations Research and Applied Statistics
George Mason University.

All three of the non-Federal installations were provided with VAX versions of the model. A brief description of the activities carried out at each of these installations is given in the text which follows. The three Federal installations will then be discussed.

The DGEM software system was provided to the General Research Corporation as a potential candidate for inclusion in a software package being developed for the Army Material Command (AMC). Since the target delivery system for the AMC software package was a PC-AT class machine, the role of DGEM was quite limited in this application.[1]

The Swedish National Defense Research Institute is currently pursuing a research project on the economic impacts of military mobilization. Their interest in DGEM is primarily pedagogical because DGEM is calibrated with U.S. data. However, because DGEM explicitly allows for major swings in both labor services and international trade, a DGEM-like model calibrated with Swedish data may provide an analytical tool which is currently unavailable to Swedish defense planners.

The activities carried out at George Mason University focused on how to perform a structured sensitivity analysis with the model. Previous work by one of the authors (Harris), produced a set of stand alone software for creating random Latin hypercube sampling schemes. Input from experts on military mobilization was then used to identify a set of key decision variables which would strongly affect the path of the economy over the mobilization period. These variables were then run through the stand alone software package to establish an experimental design for executing DGEM. In the interim, the DGEM software system was setup and tested on the George Mason University VAX. The TUTOR was first used to construct a base-case simulation runstream for the period of interest; a mobilization baseline (see Section 9.2.1) was then constructed. Both runstreams were executed and compared to results produced on the NBS computer systems. Individual runstream files for the structured sensitivity analysis were then constructed via the VAX editor. This approach was taken because it was considerably faster to copy and then edit the runstream files to comply with the experimental design than to create them directly via the TUTOR. The results of these and other activities are summarized in Chapters 9 and 10.

The three Federal agencies to which NBS provided copies of DGEM are applying it in two distinct modes of operation. The Economic Research Service is indicative of the first mode of operation; they view DGEM as a tool which is complementary to certain key models used by or within their agency. For example, forecasts produced by DGEM can be compared to those of proprietary macroeconomic models to identify areas where refinements to the problem under analysis may be called for. Similarly, the forecast values produced by DGEM may be used as

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[1] Subsequent work by FEMA has produced a PC-based version of DGEM.

inputs for certain key variables in large-scale models such as the Economic Research Service's Food and Agriculture Policy Simulator (FAPSIM). The Office of Business Analysis and the Office of Industrial Base Assessment are indicative of the second mode of operation; their focus is on major emergencies (e.g., military mobilization) and their impacts on national security. In this mode, DGEM is part of a larger system which integrates information from other models and databases. Although the applications envisioned by the Office of Business Analysis and the Office of Industrial Base Assessment are in accordance with the stated "analysis strategy" of DGEM, the degree of detail implied in these applications is much finer than currently exists within DGEM. This leads one to conclude that if DGEM is to be better integrated into these "analytical systems" it will first be necessary to construct several bridge tables which disaggregate the forecast values of selected DGEM variables to agree with those used elsewhere in the system.

All three Federal agencies have found the TUTOR to be of great assistance in understanding how the model operates, how the "scenario" of interest may be defined, and what to expect from the model in terms of output. Because the analyst can "callup" the values of key variables via the TUTOR, it provides significant insights into the assumptions underlying the base-case simulation. Furthermore, since one of the most complicated parts of the software transfer is the creation of the DGEM database as a mass storage file from the sequential file on the tape provided, the relatively straight forward programming style within the TUTOR facilitates the process of properly defining the structure of the DGEM database on the host system.

The previous discussion does not reflect the considerable use made of DGEM by FEMA, its developer, Dale Jorgenson and Associates (DJA), and by several other organizations. DGEM has been used by FEMA to simulate a number of major emergency situations. One subject which is of great importance to FEMA is that DGEM is the only macroeconomic model with demonstrated capability to simulate the U.S. economy following a nuclear attack. In addition, FEMA's experience with DGEM indicates that there appears to be no identifiable limit to the percentage increase or decrease in economic activity that DGEM can simulate if handled in stepwise increments, an attribute thought to be unique among macroeconomic models. DGEM has been employed extensively by DJA on behalf of FEMA, the Department of Energy, the Congress and other organizations. DGEM is currently in use at the Oak Ridge National Laboratory and was used extensively by the Brookhaven National Laboratory in support of the Department of Energy. DGEM was recently employed as a macroeconomic driver of the Transportation Express Model used by the Department of Transportation in the training of National Defense Executive Reservists.

By and large, the NBS experience with DGEM has been quite positive. The relative completeness of the software documentation simplified our initial efforts at setting up the model on the original UNIVAC 1100-82 computer system. The code conversion which followed immediately thereafter and the development of the TUTOR produced a deeper understanding of the model's capabilities and limitations. The success in moving between computer systems and being able to replicate results was also quite encouraging.

Based on our work with the model and feedback from other parties, it is clear that DGEM can produce information which provides significant insights into a wide-variety of policy issues. However, one should recognize that some of these advantages may be adversely impacted if nothing is done to remedy two deficiencies. These deficiencies, as perceived both by the NBS project team and other informed parties, are the lack of a software maintenance plan and the highly aggregated nature of the DGEM solution.

The need for a software maintenance plan has become increasingly important over the past year. This need stems from three interdependent sources;

(1) the development of the TUTOR;

(2) the incorporation of monetary policy into the model; and

(3) the requirement to revise portions of the database to accommodate the previously-mentioned enhancements.

To a certain extent the current "clearinghouse" role of NBS has enabled users to obtain the most up-to-date information on the model. However, this role needs to be formalized to ensure that all users have the benefit of the latest software enhancements, as well as revisions to the database and documentation.

The need for increased sectoral detail in DGEM has been recognized by a number of modelers for sometime. Although this is a serious limitation of the model for some applications, it may cause little or no problem for others. In areas where a lack of sectoral detail is a problem, it may be possible to employ bridge tables as a solution. Two areas where this approach appears feasible are: (1) a bridge between the various military procurement categories and the DGEM vector of final demands; and (2) a bridge between the DGEM solution and the sectors defined by the Commerce Department's 4-digit Standard Industrial Classification (SIC). Whereas the construction of the first bridge table is straightforward,[1] the second may require the redefinition of some internal variables and entail a restructuring of the source code. Both sets of bridge tables should be studied by a DGEM user group to define their use and assess their technical merits.

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1 Such a bridge table could be incorporated directly into the TUTOR. Data for constructing the bridge table exists both within the Defense Department and the Commerce Department (see Appendix D).

8. THE DGEM DATA BASE

The DGEM database consists of 19,327 entries for each of 43 years (i.e., 1958 through the year 2000). Of the 19,327 entries for each year 5,903 are endogenous variables, 1,643 are exogenous variables, and 11,781 are coefficients. The estimation of the model over the historical period (i.e., 1958 to 1974) used a database constructed by Jack Faucett and Associates.[1] The Faucett database contains annual price and quantity data on 11 types of energy and over 30 intermediate inputs for 35 producing sectors of the U.S. economy over the years 1958 through 1974.

Since work began on DGEM in the mid 1970's, several studies have examined the Faucett database. Two studies which are particularly noteworthy for their thoroughness and methodological approach are due to Berndt, Fuss and Waverman[2] and Hazilla and Kopp.[3] The latter study provides many insights into the Faucett database because it examines the nature of factor adjustment, the treatment of capital aggregation, alternative capital service price formulations, the aggregation of energy types, the specification of technological change, and the choice of scale economies. One conclusion from the Hazilla and Kopp study which is of importance to the DGEM database is that substitution elasticity estimates are quite sensitive to the capital service price formulation. In a subsequent review of the Hazilla and Kopp study, Berndt points out that the rate of return used in DGEM is based on realized profits and taxes, and thus is an ex post rather than an ex ante rate of return.[4,5] This poses a methodological problem because the choice of the capital service price formulation confuses ex ante with ex post costs of capital. Berndt asserts that if DGEM were estimated using the theoretically appropriate ex ante cost of capital (e.g., the Moody Baa bond yield which captures average risk), that the new parameter and elasticity estimates would differ considerably from those now found in the DGEM database.

As a part of the original task of building and testing DGEM, the developers prepared a number of base-case simulations. Three sets of base-case simulations are reviewed in this section; they are:

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[1] Jack Faucett and Associates, Development of 35 Order Input-Output Tables, 1958-1974, Final Report, Washington, DC: Federal Preparedness Agency, 1977.

[2] Berndt, E.R., M. A. Fuss and L. Waverman, Empirical Analysis of Dynamic Adjustment Models of the Demand for Energy in U.S. Manufacturing Industries, 1947-1974, Palo Alto, CA: Electric Power Research Institute, 1980.

[3] Hazilla, M., and R. J. Kopp, Industrial Energy Substitution: Econometric Analysis of U.S. Data, 1958-1974, Palo Alto, CA: Electric Power Research Institute, 1984.

[4] Berndt, E. R., "Summary/Critique of Industrial Energy Substitution: Econometric Analysis of U.S. Data, 1958-1974," mimeo, 1985.

[5] Since the ex post rate of return is used within DGEM as the ex ante cost of capital, one would conclude that the firm is always in equilibrium.

(1) model performance over the historical period (i.e., simulations between 1959 and 1974);

(2) model performance between 1975 and 1981, when published data on certain key variables was available; and

(3) the base-case projections (i.e., simulations between 1982 and the year 2000).

The historical simulations were of two types, static and dynamic. Both types of simulation were compared to the realized values of personal consumption expenditures, gross private domestic investment and GNP from the National Income and Product Accounts (NIPA).[1] All comparisons used as a goodness-of-fit measure the root-mean-squared error (RMSE) as a percent of the actual mean.

The goodness-of-fit measures associated with the three NIPA components for both the static and dynamic simulations are recorded in Table 8.1. For the static simulation, the maximum RMSE is 8.4 percent for nominal investment and 11.9 percent for real investment (calculated in 1972 dollars). The maximum and minimum RMSE figures for the sectoral prices are 14.7 percent for Tobacco Manufacturers and 2.0 percent for Gas Utilities. The corresponding figures for sectoral quantities are 49.5 percent for Tobacco Manufacturers and 3.0 percent for Transportation Equipment and Ordnance, except Motor Vehicles.

For the dynamic simulation, the maximum RMSE is 12.2 percent for nominal investment and 24.0 percent for real investment. The maximum and minimum RMSE figures for the sectoral prices are 58.7 percent for Tobacco Manufacturers and 3.7 percent for Primary Metal Industries. The maximum and minimum RMSE for the sectoral quantities is 455.2 percent for Tobacco Manufacturers and 3.1 percent for Transportation Equipment and Ordnance, except Motor Vehicles. Other dynamic simulations were performed within the historical period which did not include the years prior to 1960. These simulations produced significantly better agreement with published data.

In evaluating DGEM's performance between 1975 and 1981, one must recognize that while many variables were aligned to observed values, many were not. In most cases, the simulated values for these compare favorably with information developed from published sources. The discussion which follows provides several specific examples from which the reader can gauge the model's performance.

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[1] Simulations of the 36 DGEM Over the Historical Period, Lexington, MA: Data Resources, Inc., 1980.

Table 8.1 Goodness-of-Fit Measures for Three NIPA Components During the Historical Period[1]

NIPA Component	Static		Dynamic	
	Nominal	Real[2]	Nominal	Real[2]
Personal Consumption	1.8	2.7	6.2	9.2
Investment	8.4	11.9	12.2	24.0
GNP	4.0	4.1	3.2	10.7

Between 1975 and 1981, actual inflation exceeded that predicted by the model. The model also underestimates inflation in export and import prices, but it accurately tracks the relative price trend which is important for considering exchange rate movements.

The underestimate of ouput inflation has its origins with projected growth in input prices. The price of labor received by households, PLB, was used as the instrument for nominal consumption, CNIA. Simulated growth in PLB averaged 8.3 percent annually from 1974 through 1981. This compares with a 9.0 percent annual rate for hourly labor compensation in the nonfarm business sector over the same period. With broadly, though not exactly, similar coverage of the labor market, the model predicts somewhat slower growth in labor costs which has a corresponding impact on output prices. Growth in capital prices is in close agreement with past trends.

The model slightly overestimates income growth. Over the 1974 through 1981 period, national income (in current dollars) grew at an average annual rate of 10.6 percent. The nominal income variable in DGEM, Y, rose moderately faster, at an average rate of 11.6 percent annually. This combined with lower inflation implies more rapid growth in real incomes within DGEM than did actually occur. Since spending is aligned to observed history, the balance is saved, adding to private wealth. The mechanisms that promote this additional saving are the after-tax rates of return on capital and wealth.

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[1] All entries are the RMSE as a percent of the actual mean.

[2] Calculations are based on 1972 dollars.

A final area for comparison concerns economic structure. Periodically, the U.S. Department of Labor publishes time-series data on domestic output for all input-output industries. These data can be aggregated to conform to the interindustry structure represented in DGEM. Table 8.2 compares the Labor and DGEM data for the years 1974 and 1980. Data from the model for 1974 are as developed by Jack Faucett and Associates, while the data for 1980 are the results of simulations. Reference to Table 8.2 shows close agreement in the relative importance of each industry and the changing nature of that importance over time. For example, the shift away from construction and the so-called "smokestack" industries (e.g., primary metals, motor vehicles) and toward communications, trade, finance, and services is captured in the simulation.

The base-case projection represents a simulated path of economic growth and structural change from 1982 to the year 2000.[1] The projection reflects both the assumed values of the exogenous variables and the structure of DGEM itself. The exogenous variables values reflect best estimates incorporating information available in 1983. Correspondingly, the base-case projection might be viewed as a "best estimate" of the economic future, as seen from the perspective of 1983.

The long term trends in real economic growth over the 18-year period are recorded in Table 8.3. Economic growth is projected to average just over 3 percent a year. This represents continued growth at rates less rapid than during the World War II to 1973 period but more rapid than during the 1973 to 1983 decade.[2] There are two reasons for this. First, the 1982 starting point was in a recession, so the 1980's growth reflects both recovery and underlying growth. Second, the rate of labor growth is considerably less rapid in the 1990's than in the 1980's. All principal uses of economic production (e.g., personal consumption expenditures, investment, and government purchases) show sustained growth. However, the growth rate for the volume of government purchases is, by assumption, less rapid than for the economy as a whole, permitting private spending to grow somewhat more rapidly than GNP.

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[1] The description of the base-case projection follows closely that given in R.J. Goettle and E.A. Hudson, Final Report on the Dynamic General Equilibrium Model, Cambridge, MA: Dale Jorgenson and Associates, 1984.

[2] The base-case projection assumes a slight acceleration in inflation from recent rates, averaging 5.3 percent over the 18-year period.

Table 8.2 Structure Of Total Domestic Output[1,2]

DGEM Sector Number	1974		1980	
	Labor	DGEM	Labor	DGEM
1	4.1	4.5	4.5	4.7
2	0.2	0.2	0.1	0.2
3	0.3	0.3	0.3	0.2
4	0.8	0.7	0.7	0.6
5	0.2	0.2	0.2	0.2
6	7.5	7.3	6.5	6.1
7	6.2	6.1	6.2	6.0
8	0.5	0.5	0.4	0.4
9	1.1	1.2	1.2	1.3
10	1.7	1.9	1.6	1.7
11	1.1	1.1	1.0	1.0
12	0.5	0.6	0.5	0.6
13	1.6	1.6	1.5	1.5
14	1.5	1.6	1.6	1.7
15	2.6	2.8	2.6	2.8
16	1.7	1.6	1.7	1.5
17	1.7	1.9	1.7	1.9
18	0.3	0.3	0.2	0.2
19	1.1	1.1	1.0	1.0
20	3.7	3.6	2.5	2.5
21	2.5	2.8	2.2	2.5
22	4.1	4.2	4.0	4.3
23	3.0	3.2	3.4	3.6
24	3.2	3.3	2.7	2.8
25	2.0	2.1	2.2	2.1
26	0.9	0.9	0.9	1.0
27	0.6	0.7	0.6	0.6
28	4.3	4.5	3.8	3.7
29	2.0	2.1	2.8	3.1
30	1.7	1.7	1.9	1.9
31	1.0	0.9	0.8	0.8
32	13.5	11.2	13.7	11.9
33	9.3	9.1	10.7	10.4
34	12.5	13.1	1.0	0.9
35	1.0	1.1	1.0	0.9

1 R.J. Goettle and E.A. Hudson, Final Report on the Dynamic General Equilibrium Model, Cambridge, MA: Dale Jorgenson and Associates, 1984.

2 Percent of total real output across 35 industries.

Table 8.3 Average Annual Percentage Growth Rates for Constant Dollar Variables

Variable	Time Period		
	1982-1990	1990-2000	1982-2000
Consumption	3.5	3.1	3.3
Investment	3.7	3.9	3.8
Government Purchases	2.0	1.5	1.7
Real GNP	3.2	3.0	3.1

DGEM explicitly recognizes that economic growth tends to be cyclical rather than steady. Hence, there will be cycles around the growth trends given in Table 8.3. Annual growth rates for the same four variables recorded in Table 8.3, which incorporate these cycles, are recorded in Table 8.4. The different types of final demand (e.g., personal consumption expenditures, investment, and government purchases) display very different patterns over the business cycle. Government purchases are the most stable since they reflect political rather than market forces. Although government purchases may show uneven growth rates, these are not related to the business cycle and generally even work to dampen the magnitude of the cycle. Personal consumption is intermediate. Service and nondurables purchases are very stable, durable purchases are cyclical, so that overall consumption volumes show only a mild cycle. Private investment is the most volatile of the main spending components. In recession years, investment growth is zero or even negative; in the recovery years, investment volumes grow much more rapidly than the rest of the economy.

The composition of final demand between personal consumption expenditures, private investment and government purchases (i.e., how the output of the economy is used) is projected to show substantive change. Table 8.5 shows the composition of final demand in both current and constant dollar terms.

Perhaps the most striking feature is the decline in the share of the final output of the economy devoted to government purchases.[1] This feature is an assumption of the forecasts, it is not an output of the model. The declining share of government leaves a greater percentage of output available for the private sector. Both consumption and investment share in this increase.

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[1] This refers to Federal, state and local government purchases of goods and services. It does not include government transfers, a major component of government expenditures. These figures do not necessarily imply a decline in the ratio of government expenditures to GNP.

Table 8.4 The Business Cycle: Annual Percentage Growth Rates, 1982-2000

Year	Variable			
	Personal Consumption	Private Investment	Government Purchases	Real GNP
1983	2.8	5.5	2.1	2.2
1984	4.5	7.3	2.5	4.4
1985	4.9	5.0	2.3	4.5
1986	4.0	-0.7	1.9	2.9
1987	2.6	1.3	1.7	2.6
1988	3.5	7.5	1.8	3.8
1989	2.4	0.6	1.8	2.2
1990	3.0	3.8	1.8	2.9
1991	2.6	5.7	1.6	3.0
1992	2.5	4.4	1.6	2.6
1993	2.0	0.9	1.3	1.9
1994	3.9	4.2	1.4	3.5
1995	4.1	6.9	1.4	4.1
1996	4.1	4.4	1.4	3.7
1997	2.7	0.3	1.4	2.3
1998	2.8	2.6	1.5	2.5
1999	2.9	3.0	1.4	2.8
2000	3.8	6.2	1.4	3.7

Table 8.5 Composition of Final Demand as a Percent of GNP, 1982-2000[1]

Variable Name	Current Dollars			Constant Dollars		
	1982	1990	2000	1982	1990	2000
Personal Consumption	64.5	65.5	65.7	64.8	66.3	66.9
Private Investment	13.8	15.2	16.4	13.4	14.0	14.8
Government Purchases	21.2	18.9	17.5	19.7	18.0	15.7

[1] Net exports, a component of GNP, are not shown separately in this table.

However, it is projected that the greater part of the increase goes to consumption. Personal consumption is projected to rise from around 64 percent of real GNP to over 66 percent. Investment rises too but a substantial part of this rise reflects cyclical features, recovery from the low investment share in the 1982 starting point. Aside from cyclical features, the investment share of real GNP increases by about one percentage point.

DGEM explicitly models 36 producing industries, the output of each, the disposition of this output, and the inputs into each. In fact, the macroeconomic picture is just an aggregation of these industry level developments. Table 8.6 ranks the industries in terms of volume growth rates over the 1980's (i.e. average annual growth in the volume or quantity of sales). These industries range from communications, the fastest growing, at almost 8 percent, all the way down to tobacco products, zero growth, and crude petroleum and gas, negative growth. It is difficult to generalize a pattern as to which industries show rapid growth and which show slow growth since performance depends not only on demand considerations (such as the demand response to population and income increase) but also on supply considerations (covering input mix and productivity, operating through their effect on prices). However, a rough generalization is as follows. The fast growing industries are high technology (communications, instruments, plastics, chemicals, electrical machinery) and services (finance/insurance/real estate, services, trade). The slow growing industries are extractive and resource processing (crude petroleum and gas, gas utilities, petroleum refining, nonmetallic mining, metal mining, coal mining) and population-related (tobacco products, leather, agriculture, food products). The medium growing industries are the established manufacturing industries (apparel, textiles, motor vehicles, primary metals, wood products).

The differences in growth rates are substantial. An industry such as communications, growing at 7.8 percent, compared to the overall average growth rate of 3.2 percent, will more than double its relative size over the 1982-2000 period; for example, the industry provided 3 percent of total gross output in 1982, but by the year 2000 its share will be 7.5 percent. Or services, growing at 4 percent, will increase their relative size by 15 percent, expanding from 14 percent to 16 percent of total gross output. At the other end of the range, an industry, such as tobacco products, showing zero growth would find its relative size cut by over 40 percent. Or, agriculture-forestry-fisheries, growing at 1.7 percent, would decline in size from 4.5 percent of gross output in 1982 to just over 3 percent in 2000.

These considerations lead to two general conclusions. First, there will be major changes in the industrial mix by the year 2000. The high technology and service industries will become more important, the resource-based industries will be relatively smaller than in 1982. Second, even though major restructuring will occur, the structure of the American economy in the year 2000 will not, in the very broadest sense, be fundamentally different from the way it was in 1982.

Table 8.6 Industry Growth Rates[1]

Industry	Rate	Rank
Agriculture, Forestry, Fisheries	1.7	32
Metal Mining	2.7	26
Coal Mining	2.6	27
Crude Petroleum, Natural Gas	-0.7	36
Nonmetallic Mining and Quarrying	2.0	30
Construction	2.8	25
Food-Kindered Products	2.1	29
Tobacco Manufactures	0.0	35
Textile Mill Products	3.0	21
Apparel	2.9	24
Lumber and Wood Products	3.0	22
Furniture and Fixtures	4.4	8
Paper and Allied Products	3.9	12
Printing and Publishing	3.7	14
Chemicals	5.4	4
Petroleum Refining	1.2	32
Rubber and Miscellaneous Plastic Products	6.3	3
Leather	1.0	33
Stone, Clay, and Glass	3.2	19
Primary Metal Industries	3.0	20
Fabricated Metal Products	4.0	11
Machinery, Except Electrical	4.0	10
Electrical Machinery	4.6	7
Motor Vehicles and Equipment	3.0	23
Transportation Equipment and Ordanance, Except Motor Vehicles	3.7	15
Instruments	7.7	2
Miscellaneous Manufacturing	4.9	5
Transportation	3.7	13
Communications	7.8	1
Electrical Utilities	3.5	17
Gas Utilities	0.3	34
Trade	3.6	16
Finance, Insurance, and Real Estate	4.8	6
Services	4.0	9
Government Enterprises	3.3	18
Miscellaneous	2.2	28

[1] Average annual percentage growth in sales quantity, 1982 to 1990.

9. THE MOBILIZATION SCENARIO

The mobilization scenario analyzed with DGEM is patterned after an unclassified scenario approved by F. C. Ikle, the DoD Under Secretary for Policy. Basically, the scenario indicates a conventional war of three years duration in Europe, the Persian Gulf, and Korea. For purposes of the current study, a one year warning period is assumed. The scenario also provides the analyst with considerable latitude in evaluating how changes in combinations of numerical values for key variables, thus describing wars of greater or lesser intensity, affect the U.S. industrial infrastructure.

The analysis of the mobilization scenario was carried out in two stages. In the first stage, a mobilization baseline was constructed which documented the departures for key variables from the base-case values (i.e., those contained in the data file) due to the period of mobilization and conflict. The results from the first stage of the analysis provided information on gross-level changes in the NIPA components, as well as measures of the economic impacts of mobilization on a sector by sector basis.

In the second stage, six variables were varied in combination according to an experimental design. The six variables which were the subject of the structured sensitivity analysis and their names, as they appear in the tables which follow, and in Appendix E are:

1. Federal defense purchases, GZ(1);
2. Federal nondefense purchases, GZ(2);
3. The Federal deficit, DG;
4. The efficiency with which capital is employed, AKD;
5. The rate of depreciation of capital, U; and
6. The effective supply of labor services, LB.

The structured sensitivity analysis was based on Monte Carlo techniques. The objective here was to evaluate how uncertainty in the values of the six input variables just mentioned translated into changes in the level and composition of the NIPA components, capital services and energy consumption.

9.1 SPECIFICATION OF THE MOBILIZATION BASELINE AND THE STRUCTURED SENSITIVITY ANALYSIS

The period of the mobilization follows that of the unclassified DoD scenario and is assumed to be 1983 through 1986. The first year represents a period of buildup prior to the onset of hostilities. For each year of the mobilization, values for key economic variables were specified. Once the mobilization baseline had been established, a structured sensitivity analysis was performed. The values of the six variables which were the subject of the structured sensitivity analysis, their base-case values and their values in the mobilization baseline are compared at the end of this section. The specification of the military mobilization scenario presented in this chapter is as follows:

1. Government purchases;
2. Labor services;
3. Capital services;

4. Foreign trade;
5. Fiscal policy;
6. Structured sensitivity analysis; and
7. Tabular summary.

Government Purchases

Defense purchases are central to any mobilization effort. Through the TUTOR, it is possible to control both the level and composition of defense purchases. However, for the case at hand, only the level is increased so that all defense purchases are increased in the same proportion. Defense purchases are increased by 50 percent in 1983, prior to the onset of hostilities, and by 80 percent in 1984, 120 percent in 1985, and 150 percent in 1986. These increases are relative to the base case, or the economic conditions in the absence of mobilization. Federal nondefense purchases are increased by 25 percent in the first year and by 50 percent for the three following years.

Labor Services

During the mobilization, many additional people will be recruited or conscripted into the armed forces. This is directly taken into account through the increase in defense purchases. However, it is assumed that mobilization measures will also be applied to the civilian population and the civilian labor force. Additional people are assumed to be induced or pressed into the labor force. To reflect this, the labor force participation rate is increased by 4 percent in every year. Workers are also assumed to work longer hours, through overtime or just through an extension of the standard workweek. Average hours per week are raised by 13 percent. But, these changes are likely to adversely affect labor efficiency. Consequently, the average efficiency of each hour of labor is reduced by 7 percent. These three factors taken together produce a 9 percent increase in the effective supply of labor services.

Capital Services

A forced increase in capital use is assumed. This corresponds to the more intensive use of existing capital, as plant and equipment is used more hours per week, and the inclusion of emergency capacity. The overall increase in the efficiency with which capital is employed is taken to be 5 percent. This figure is a very conservative estimate of the potential for increasing the efficiency of the capital stock, since estimates of emergency capacity which can be brought on line within one year frequently exceed peacetime capacity levels by 25 percent. However, even this modest increase, is likely to accelerate the wear and tear on capital. Accordingly, the rate of depreciation of capital is increased by 10 percent.

Foreign Trade

It is assumed that all imports will be threatened. An across the board reduction of 20 percent in imports is planned. Also, in order to ensure that domestic requirements are satisfied first, an across the board reduction of 50 percent in exports is planned.

Fiscal Policy

The major emphasis here is the Federal deficit, since government purchases have already been addressed. The government deficit is constrained to exceed the base-case levels by fixed percentages. Tax rates are increased in order to secure the additional revenue that is required to maintain the targeted budget deficit in the face of higher federal spending. This means that the increase in government expenditure is paid for in part by an increase in taxes and in part by increased deficits. This mixed strategy was designed to strike a balance between increased investment and inflationary pressures. For example, if the mobilization were financed by taxes, it would not come at the expense of investment, since the government is not claiming an additional share of the capital market in order to finance defense purchases, but would come from consumption, since it is households and consumers who carry the main burden of taxes. If, in contrast, the mobilization were deficit financed, then the government would be claiming a larger share of investible funds so investment rather than consumption would likely carry a greater burden of the mobilization (i.e., private investment is crowded out). For the case at hand, the Federal deficit is allowed to increase (over the base-case values) by 50 percent in 1983 and by 80 percent in 1984 through 1986.

Structured Sensitivity Analysis

Because the values of many key variables in a mobilization scenario are not known with certainty, it is advisable to select a small set, whose impact is likely to be substantial, and subject them to a structured sensitivity analysis. Variations in the values of these input variables translate into variations in the values of the output or endogenous variables in such a manner that the economic impacts of shocks to the system can be measured quantitatively.

The approach selected for this study makes use of recent work by McKay, Conover, and Beckman[1] and by Harris.[2,3,4] Their work is based on the method of

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[1] M.D. McKay, W.H. Conover, and R.J. Beckman, "A Comparison of Three Methods for Selecting Values of Input Variables in the Analysis of Output from a Computer Code," Technometrics, Vol. 21, No. 2, 1979, pp. 239-245.

[2] C.M. Harris, "An Assessment of Climatological Uncertainties Using Monte Carlo Analysis," in Selected Assessment Strategies Applied to Short-Term Energy Models, Gaithersburg, MD: National Bureau of Standards, NBSIR 83-2672, 1983, pp. 30-54.

[3] C.M. Harris, Issues in Sensitivity and Statistical Analysis of Large-Scale, Computer-Based Models, Gaithersburg, MD: National Bureau of Standards, GCR 84-466, 1984.

[4] C. M. Harris, Computer Generation of Latin Hypercube Sampling Plans, Gaithersburg, MD: National Bureau of Standards, NBS GCR 84-476, 1985.

model sampling. The method of model sampling is a procedure for sampling from a stochastic process to determine, through multiple trials, the nature and effects of a probability distribution. The method of model sampling, or distribution sampling as it is also called, has a long history of use by statisticians to derive distributions empirically that are difficult or impossible to derive by other means. It permits the effects of uncertainty to be rigorously analyzed.

The procedure employed in this study is known as the Latin Hypercube sampling scheme. The procedure, as it's name implies, is patterned after the classical Latin square. Latin squares consist of a set of permutations such that a given character or value appears only once in each row and each column. A Latin hypercube is similar to a Latin square with the important exception that it contains more rows than columns. For example, if each column is thought of as a variable and each row is a simulation number, then entries in the cells contain the values of a set of equally spaced percentiles from the parent cumulative distribution function (CDF) of the variable of interest. For the case at hand, with six variables of interest and ten simulations, the entries in the cells are the 5th, 15th, ..., 95th percentiles of the parent CDF.

In reality, the exact nature of the parent CDF (e.g., measures of central tendency and dispersion) is unknown. Estimates of the parameters (e.g., mean and variance) of the CDF can be made and uncertainty can be reduced by investigation and research. However, uncertainty can never be eliminated completely because new sources of uncertainty are arising all the time. The true specification of the CDF can only be known when mobilization is actually underway.

So that the flexibility of the procedure could be illustrated without undue attention on the characterization of the CDF, it was decided to focus on the triangular distribution. The triangular distribution was chosen because it may be specified by three values, low, median, and high, which correspond to the 0th, 50th, and 100th percentiles.

Individual values within each of the six triangular distributions were chosen aaccording to the Latin hypercube sampling scheme (i.e., the percentiles recorded in the cells). These values were then recorded in a runstream file. Each of the runstream files were then executed and the results of the simulation were stored on-line for further analysis.

Tabular Summary

The data which were the focus of the structured sensitivity analysis are summarized in Tables 9.1, 9.2 and 9.3. Table 9.1 records the base-case values of the six variables (i.e., as they appear in the DGEM data file). Table 9.2 records the values of the same six variables for the mobilization baseline case. These values are also the median values used in fitting triangular distributions to each variable. The minimum and maximum values for each of the six variables are recorded in Table 9.3. The information in Tables 9.2 and 9.3 served to define the CDF for each variable. Values were then selected from each CDF according to the Latin hypercube sampling scheme.

Table 9.1 Base-Case Values

Variable Name	Values by Year			
	1983	1984	1985	1986
GZ(1)	207.3	220.3	235.7	233.2
GZ(2)	68.3	72.3	86.9	67.62
AKD	0.146	0.159	0.160	0.156
U	0.062	0.062	0.062	0.062
LB	1037.7	1058.3	1050.9	1068.9
DG	174.0	167.3	211.9	192.5

Table 9.2 Mobilization Baseline Values

Variable Name	Values by Year			
	1983	1984	1985	1986
GZ(1)	311.0	396.5	5.8.5	583.0
GZ(2)	85.4	108.5	130.4	101.4
AKD	0.154	0.167	0.168	0.164
U	0.068	0.068	0.068	0.068
LB	1131.1	1153.6	1145.5	1165.1
DG	261.1	301.1	381.5	346.5

Table 9.3 Extreme Values Used in the Structured Sensitivity Analysis

Variable Name		Values by Year			
		1983	1984	1985	1986
GZ(1)	MIN	290.2	374.5	471.4	513.0
	MAX	331.7	418.6	565.7	653.0
GZ(2)	MIN	82.0	101.2	121.7	94.6
	MAX	88.8	115.7	139.0	108.2
AKD	MIN	0.150	0.164	0.165	0.161
	MAX	0.156	0.170	0.171	0.167
U	MIN	0.065	0.065	0.065	0.065
	MAX	0.071	0.071	0.071	0.071
LB	MIN	1110.3	1132.4	1124.5	1143.7
	MAX	1151.8	1174.7	1166.5	1186.5
DG	MIN	226.2	284.4	339.0	308.0
	MAX	295.8	317.9	423.8	385.0

9.2 IMPACTS OF THE MOBILIZATION SCENARIO ON THE NATIONAL ECONOMY

9.2.1 Analysis of the Mobilization Baseline

The volume of economic output increases as a result of mobilization. Demand increases due to high government purchases, while the effective volume of available resources also rises, as a result of the increase in capital and labor services. Thus, demand is pulling production higher while resources and capacity permit an accompanying increase in production.

Total Production

Real GNP changes in 1983 are estimated to be:

1. Base case real GNP \$3277.7 (10^9);

2. Real GNP with mobilization \$3634.4;

3. Increase in real GNP \$356.7; and

4. Percentage increase in real GNP 10.9

The higher level of real GNP is continued from 1984 through 1986 where the relative increases are 11.5, 11.3, and 10.8 percent.

Thus, the mobilization stimulates economic activity. Production responds; the entire level of economic activity is increased. Real GNP increases by an average of 11.1 percent compared to the base case economic situation. How is this increase in production sustained? At an aggregate level, the increase can be separated into three components:

1. Additional input of labor services;
2. Additional input of capital services; and
3. Increases in productivity.

Use of Output

This gain in production is used in the form of higher levels of final demand. But, which types of spending benefit from the higher level of economic activity? Clearly, government purchases will increase substantially, since the rise in defense spending is the initiating factor in all these adjustments. But, do consumption and investment share in the greater level of production? The average increases in final demand during the period of mobilization are:

1. Personal consumption expenditures 6.2%
2. Gross private domestic investment 13.1%
3. Government purchaes 38.0%
4. Exports -50.0%
5. Imports -20.0%

Consumption and investment rise and government purchases rise most of all. Thus, the gains from the shift to mobilization do not accrue to businesses. Instead, the gains go to the government. Mobilization generates a shift in economic structure, away from business and investment and consumption and towards government activity.

Economic Growth

The initial effect of the mobilization is to raise the level of economic activity. Real GNP in 1983 is some 10.9 percent higher than in the base case. But, does this mean that the mobilization generates more rapid economic growth? In fact, the mobilization does not increase economic growth. Certainly, the growth in real GNP from 1983 is accelerated. But, this corresponds to a one-time jump to a higher level of economic activity. Once production is at this new, higher level, growth rates revert to their former pattern. Thus, mobilization generates a single shift to more production, as both final demand and available resources are boosted. Mobilization does not generate a continuing gain in achievable rates of economic growth.

This is an important point, for it means that the early gains under mobilization will not be repeated. A higher level of production is sustainable, at least for some time, but large continuing gains are not realistic.

Prices

The mobilization does affect the level of prices. It might be expected that inflation will accelerate (i.e., that the rate of increase in the general level of prices will rise). This is exactly what happens. The GNP price deflator shows an acceleration, over the GNP price deflator for the base case, of 2.3 percent in 1983, 4.5 percent in 1984, 9.7 percent in 1985 and 13.8 percent in 1986. The estimated inflationary impact is not immediate. It is not until the third year of the mobilization that the inflationary effects become striking.

Industry Effects

Different industries are affected to different degrees by the mobilization. These impacts reflect several forces. The rise in defense purchases; and a change in input patterns accompanying any restructuring in relative prices.

Overall production rises, on the average, by 10.1 percent compared to the base-case conditions. The percentage change in individual industries ranges from a decline of 11.5 percent for metal mining to a rise of 32.1 percent for transportation equipment and ordnance.

Several industries have increases in output volumes. These involve crude petroleum and gas, petroleum refining, gas utilities, electric utilities, construction, services, and, with the largest gain, military transport equipment and ordnance. Some of these are expected as they are the materials directly purchased for defense purposes. Others, however, reflect the indirect effects, as requirements work their way through the industrial system. For example, military transportation equipment and ordnance and petroleum are directly related to defense purchases, whereas most of the remaining industries are indirectly related.

In contrast, some industries are estimated to experience a reduction in volume. Even though overall economic activity is higher, these industries are less needed than in the base case.

Information on specific industries can be used in several ways. As a projection, it estimates what would happen under mobilization conditions. As a prescription, this indicates which industries are most important to the mobilization effort. Industries with a greater than average increase in output are of greater than average importance. Some of these are obvious, given their direct role in defense purchases. Others, however, are less obvious and the ability to reveal such industries is an important benefit from an analysis such as this. By indicating the relative importance of each industry, this analysis can help mobilization planning if policies were to be implemented to affect the allocation of resources (i.e., the essence of such allocations is to differentiate higher from lower priority claimants on available resources).

A related application of this analysis involves the identification of bottlenecks. The increases in industry outputs are the increases required to sustain the mobilization. These increases might be compared with the expansion capability of an industry based on detailed knowledge of the industry and of constraints specific to the industry. If the required expansion exceeds the maximum likely expansion, or surge capacity, then the analyst has identified a potential bottleneck. Contingency plans can then be developed to ease such bottlenecks in the event of a mobilization.

9.2.2 Results of the Structured Sensitivity Analysis

The general trends described in the previous subsection were reinforced in the structured sensitivity analysis. Consequently, the focus here is on documenting how perturbations about the values of the six key input variables given in Table 9.2 translated into changes in five major output variables. These output variables and their names are:

(1) Real Gross National Product, GNPQ;
(2) Real Personal Consumption Expenditures; CNIAQ;
(3) Real Gross Private Domestic Investment, INIAQ;
(4) Real Private Domestic Capital Services, KD; and
(5) Quantity of Energy Delivered, QED.

The first three variables are associated with the National Income and Product Accounts (NIPA); they are referred to in the text, tables and figures which follow as real GNP, real PCE and real investment, respectively. The fourth variable, KD, registers the joint effects of variations in the efficiency with which capital is employed, AKD, and capital accumulation over the mobilization period. It is important to note that capital accumulation incorporates the effects of investment and another key input variable in Table 9.2, U, the rate of depreciation of capital. For each year in the mobilization, KD is equal to the product of AKD and KL, the total real private domestic capital stock at the beginning of the year. The fifth variable measures the amount of energy delivered to the domestic economy in quadrillion BTU's (Quads). This amount is equal to the sum total of Quads delivered for electricity, coal, natural gas and petroleum.

The results obtained from the structured sensitivity analysis on each of the five major output variables are described through reference to a series of tables and figures. These tables and figures summarize three basic types of information for each variable:

(1) The equilibrium levels experienced as a result of mobilization;

(2) The percentage change (increase or decrease) over the base-case simulation as a result of mobilization; and

(3) The annual percentage change in the equilibrium levels during the period of the mobilization.

These three types of information are hereafter referred to as mobilization values, base-case deviations, and annual rates of change, respectively.

Most of the figures presented in this section make use of a graphical analysis technique known as the box plot.[1] Box plots provide a convenient means for summarizing graphically an entire data set. Box plots are essentially a graphical analysis of variance. One advantage of box plots for the structured sensitivity analysis is that they permit multiple years worth of data to be compared in a single diagram.

The box plot consists of a box with its "hinges" drawn at the 25th and 75th percentiles, respectively. The width of the box is proportional to the number of observations. The median (i.e., the 50th percentile) is marked within the box. The extreme values are marked and connected to the hinges of the box with "whiskers." The box plot thus graphically summarizes both the central tendency of the data as well as its dispersion. Non-overlapping boxes on the same plot are a strong indication that the two sets of data are significantly different. All Box plots presented in this section were generated through application of the statistical analysis package DATAPLOT.[2]

Growth in Total Production

As was shown earlier, the output of the economy increases during the mobilization. Figure 9.1 provides a graphical summary of the economic impacts of mobilization for three sets of values for real GNP between 1982 and 1986. The first year, 1982, is prior to the mobilization period and is included as a reference point. The first set of values is for the base-case simulation; these values are traced out by a solid line. These values provide a basis for comparing the output of the peace-time economy to outputs anticipated during the mobilization. The second set of values is for the mobilization baseline; these values are traced out by a dotted line. The third set of values is for the mobilization maxima (i.e., the set of highest values for each year across all simulations); these values are traced out with triangles and dashed lines.

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1 J. W. Tukey, Exploratory Data Analysis, New York: Addison-Wesley, 1977.

2 J. J. Filliben, DATAPLOT: Introduction and Overview, Gaithersburg, MD: National Bureau of Standards, Special Publication 667, 1984.

Figure 9.1 Values of Real GNP for the Base-Case Simulation, the Mobilization Baseline and the Mobilization Maxima

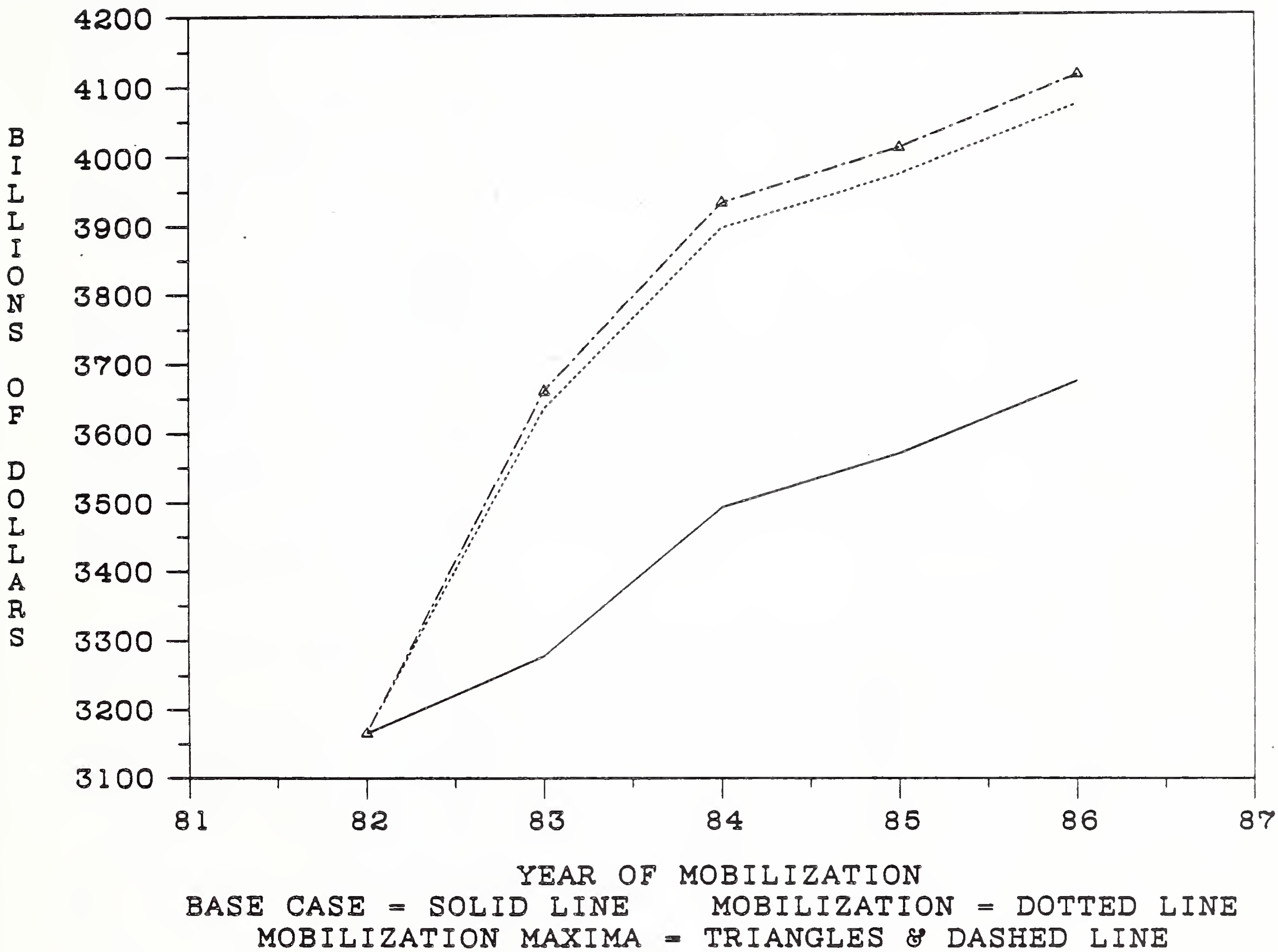
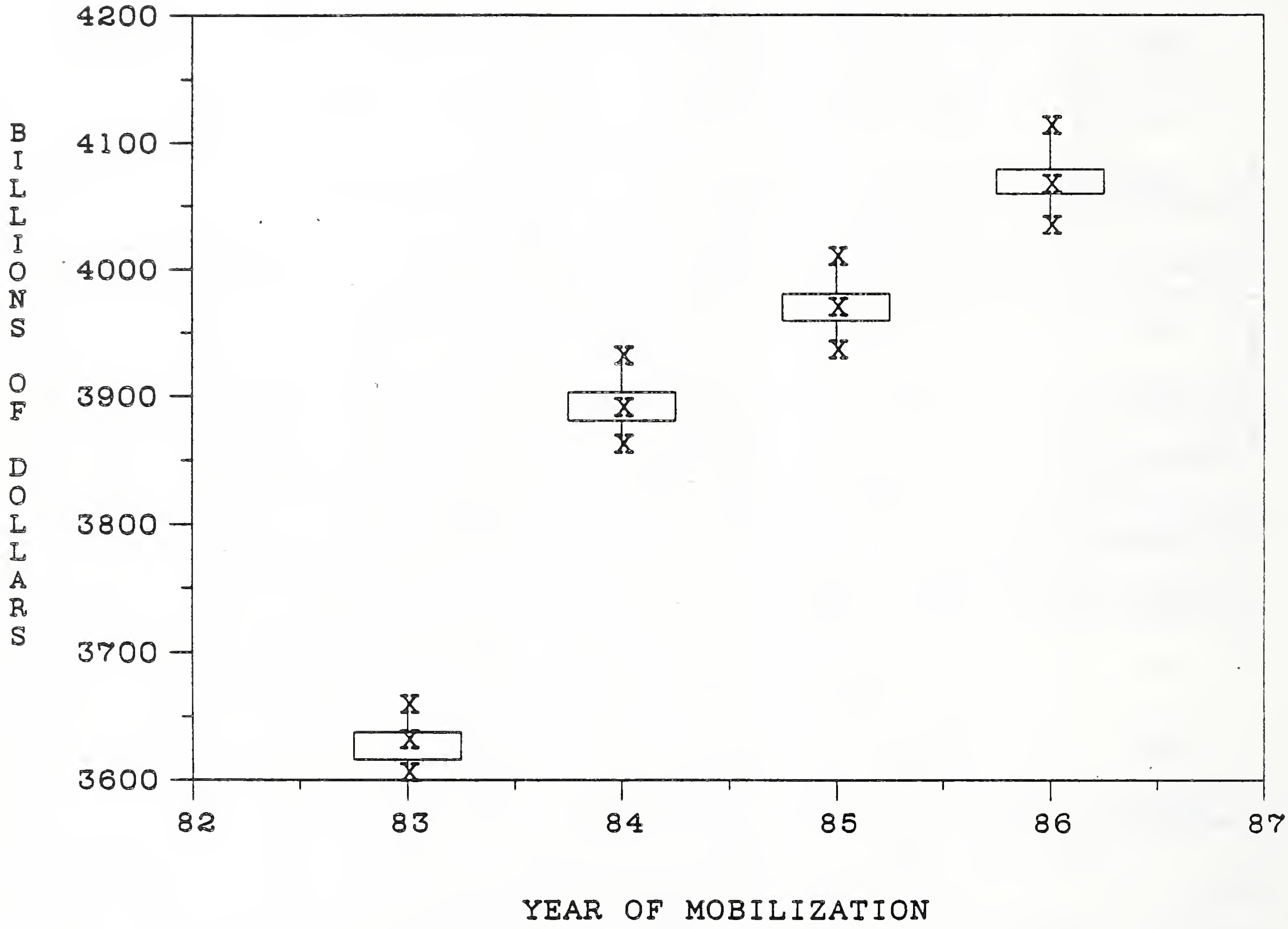


Figure 9.2 Box Plots of Mobilization Values for Real GNP



Through reference to Figure 9.1, it can be seen that real GNP increased from just under $3200 billion in 1982 to nearly $4100 billion in 1986. The figure documents the rapid increases in real GNP in 1983 and 1984. In 1985 and 1986, the economy gives indications of a return to its long-run growth trend, since the traces associated with the mobilization parallel that of the base-case scenario. The figure also shows that mobilization has resulted in a net increase of approximately $400 billion in the level of real GNP over the base-case simulation for 1984 through 1986.

Figure 9.2 is a sequence of box plots showing the range of the mobilization values for real GNP. The figure demonstrates that significant increases in the output of the economy are experienced in each year of the mobilization. A tabular summary of the data in Figure 9.2 is given in Part A of Table 9.4. From Part A of Table 9.4, it can be seen that the range (i.e., the difference between the maximum and minimum values) increases from approximately $55 billion in 1983 to nearly $80 billion in 1986. Although the standard deviation of the simulated values increases in each year, it averages about 0.5 percent of the mean. Consequently, the increases in real GNP noted earlier are statistically significant.

A quick comparison between Figures 9.1 and 9.3 documents the magnitude of the change in the output of the economy due to mobilization. Figure 9.3 indicates that the war-time economy averages an increase of approximately 11 percent over the base-case simulation. Note that the base-case deviations reach a peak in 1984 and then decline slightly through 1986. This observation is consistent with the statement made earlier that the economy returned to its long-run growth trend once the initial shocks of the mobilization worked their way through the model. Part B of Table 9.4 provides a summary of the data in Figure 9.3. These data show the significance of the initial surges, followed by the resumption of a trend.

Comparisons between Figures 9.1, 9.2, and 9.4 and the data for 1983 in Figure 9.3 illustrate how the output of the economy has grown over the mobilization period. The initial surge in government purchases produces a rapid increase in output. Reference to Figure 9.4 shows that the annual rate of change in real GNP is nearly 15 percent in 1983.[1] In 1984, the annual rate of change has slowed to approximately 7.5 percent. By 1985, real GNP has returned to growth rates consistent with a peace-time economy. Part C of Table 9.4 provides a summary of the data in Figure 9.4. These data show how the initial surge produces both a high rate of change and a high variability in that rate. By 1984, although the rate of change is still high, the variability has been reduced substantially. The variability in the growth rate then hovers around 0.1 percent through 1986. These observations lend support to the claim made earlier that mobilization produces a one-time jump to a higher level of economic activity rather than a continuing gain in achievable rates of economic growth.

[1] The annual rate of change for 1983 is computed using the 1982 value of the base-case simulation. Consequently, the annual rate of change of nearly 15 percent incorporates an underlying growth trend plus a deviation from the base-case simulation. It is for this reason that the annual rate of change for 1983 exceeds the base-case deviation for 1983.

Table 9.4 Summary Statistics for Real GNP

PART A: MOBILIZATION VALUES

YEAR	MEAN	MINIMUM	MAXIMUM	STD. DEV.
1983	3629.6	3606.4	3659.7	15.97
1984	3893.5	3862.4	3932.0	19.58
1985	3970.9	3936.7	4010.0	20.96
1986	4069.1	4035.0	4113.1	23.44

PART B: BASE-CASE DEVIATIONS

YEAR	MEAN	MINIMUM	MAXIMUM	STD. DEV.
1983	10.74	10.03	11.66	0.487
1984	11.50	10.61	12.60	0.561
1985	11.23	10.27	12.32	0.587
1986	10.77	9.84	11.97	0.638

PART C: ANNUAL RATES OF CHANGE

YEAR	MEAN	MINIMUM	MAXIMUM	STD. DEV.
1983	14.64	13.91	15.60	0.505
1984	7.27	7.10	7.44	0.107
1985	1.99	1.90	2.13	0.078
1986	2.47	2.25	2.61	0.100

Figure 9.3 Box Plots of Base-Case Deviations for Real GNP

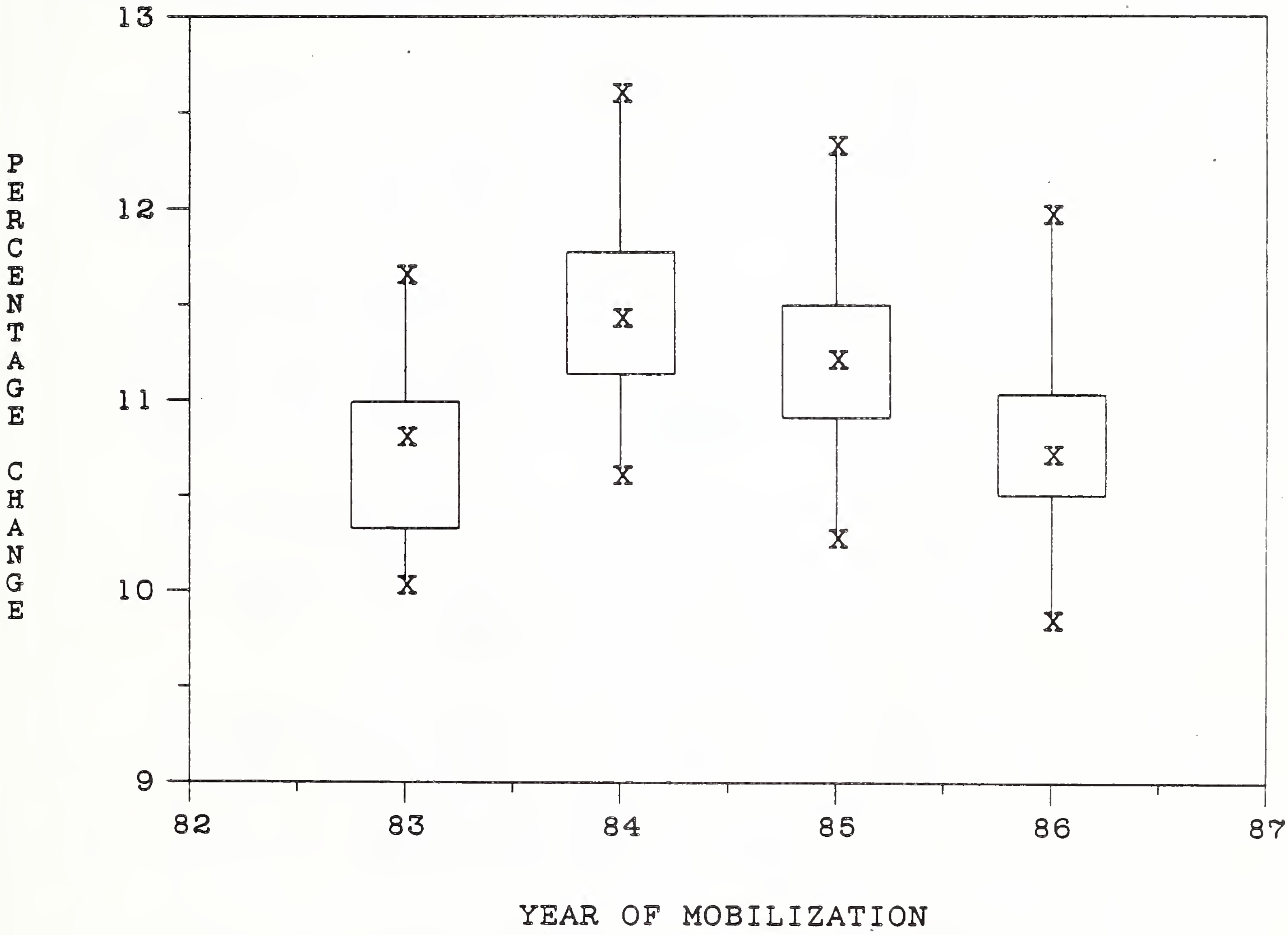
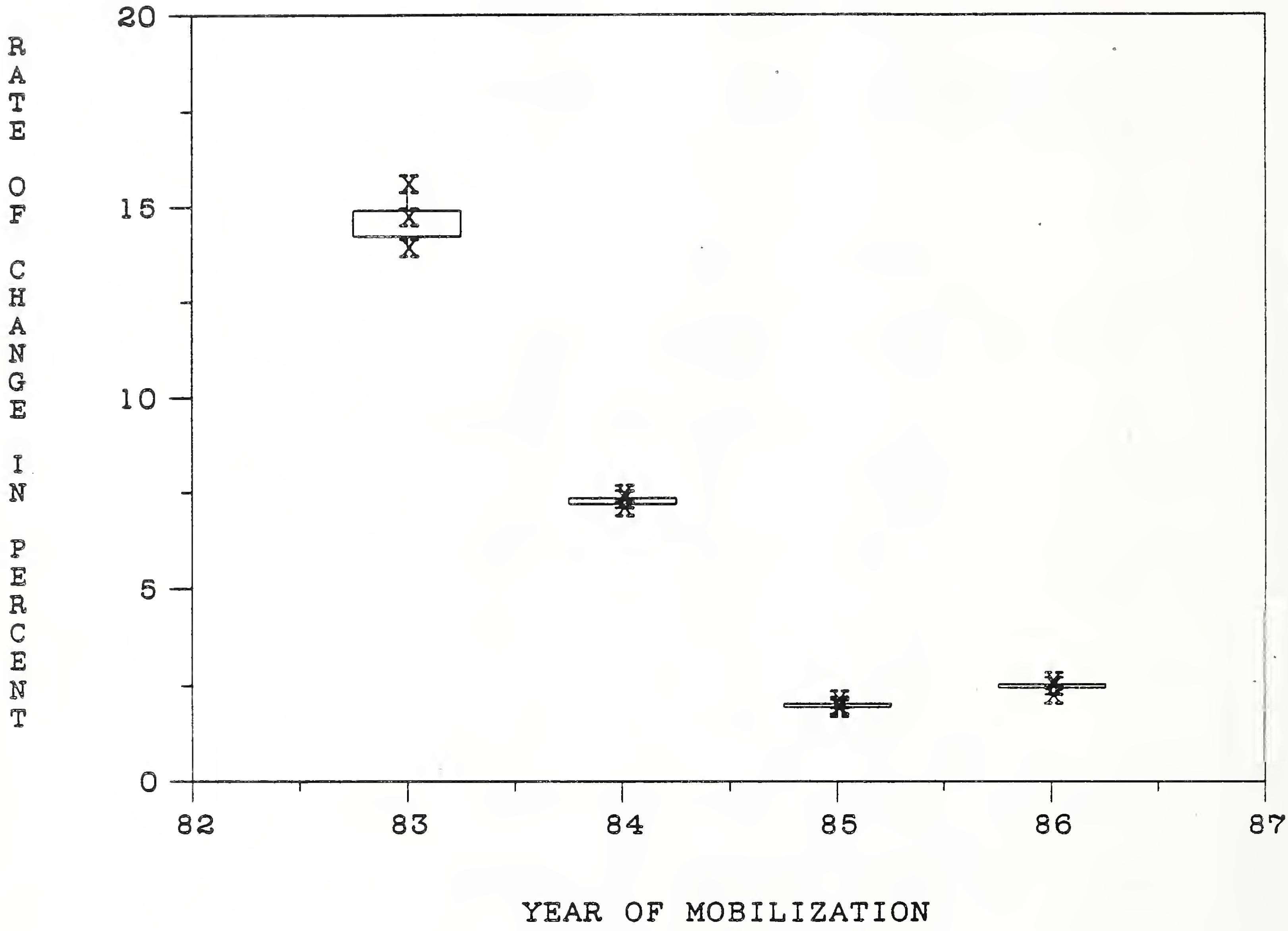


Figure 9.4 Box Plots of Annual Rates of Change for Real GNP



Use of Output

The focus of this portion of the analysis is on changes in real PCE and real investment. The other NIPA components, government purchases, exports and imports, follow the same patterns as in the mobilization baseline. Exports are reduced by 50 percent and imports by 20 percent in all simulations. The levels of government purchases were selected according to the Latin hypercube sampling scheme described earlier. The average increase in government purchases was 38 percent over the period of the mobilization.

The values of real PCE experienced during the mobilization are plotted in Figure 9.5. From the figure, it can be seen that the mobilization causes real PCE to increase substantially in 1983. The increases in real PCE for 1984 through 1986, however, are lower than in the base-case simulation.

The way in which real PCE changes during mobilization period is clearly illustrated in Figure 9.6. For example, real PCE for 1984 is significantly higher than in 1983. However, once the initial surge in government purchases has worked its way through the model, real PCE remains nearly constant. These observations are summarized in Part A of Table 9.5, where the mean value of real PCE changes by less than $20 billion between 1984 and 1986.

Comparisons between Figures 9.5 and 9.7 show that the mobilization values of real PCE are trending toward those of the base-case simulation. Furthermore, the trend seems to be significant during the latter years of the mobilization. Reference to Part B of Table 9.5 shows that the average base-case deviation is 6.2 percent. The value for 1983 is 9.6 percent whereas it is only 2.4 percent for 1986.

Figure 9.8 provides some additional insights into how real PCE changes over the mobilization period. After an initial surge, the annual rate of change in real PCE is well under 5 percent. Part C of Table 9.5 shows that the growth rate for real PCE is slightly negative for 1985 and is essentially flat for 1986.

Real Investment

The mobilization values of real investment follow cyclical rather than a secular trend. These values plotted in Figure 9.9, reflect the underlying business cycle. Investment increases sharply in 1983 and 1984, turns down in 1985 and experiences a rate of increase approximately equal to that of the base case simulation in 1986.

The box plots of the mobilization values of real investment in Figure 9.10 indicate that all changes, both increases and decreases, are likely to be highly significant. These observations are borne out through reference to Part A of Table 9.6.

Figure 9.5 Values of Real PCE for the Base-Case Simulation, the Mobilization Baseline and the Mobilization Maxima

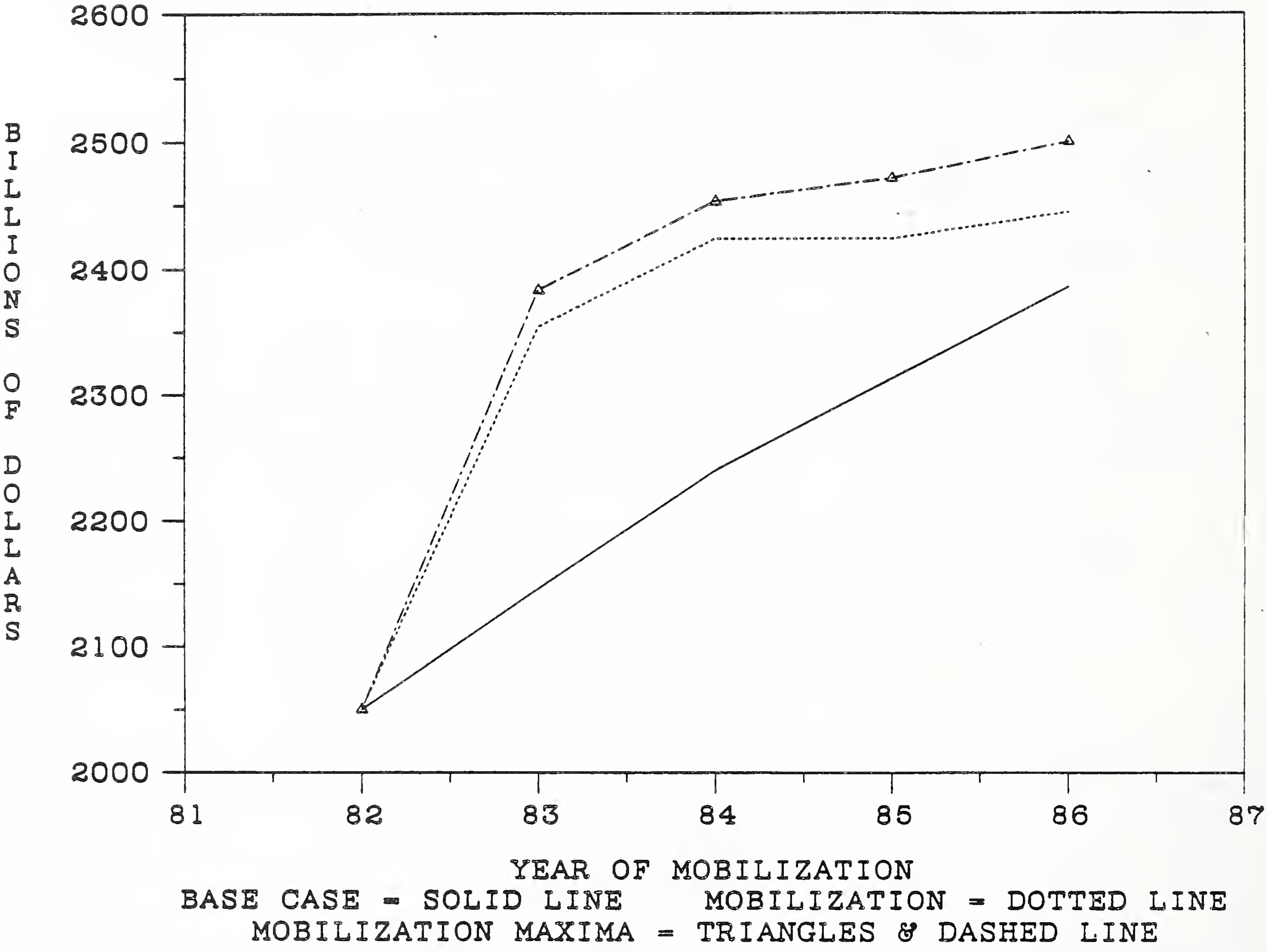


Figure 9.6 Box Plots of Mobilization Values for Real PCE

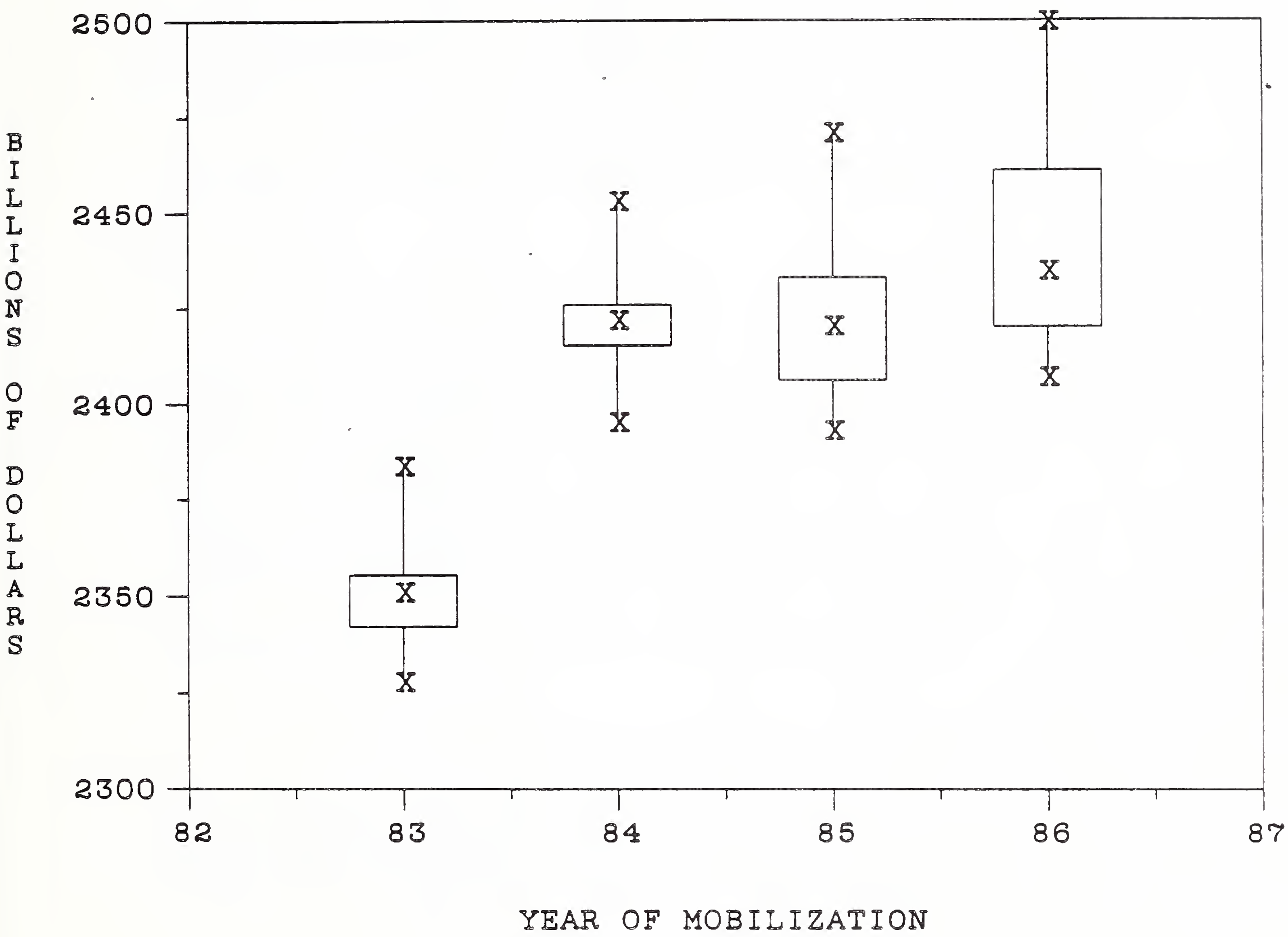


Table 9.5 Summary Statistics for Real PCE

PART A: MOBILIZATION VALUES

YEAR	MEAN	MINIMUM	MAXIMUM	STD. DEV.
1983	2351.6	2327.7	2383.6	14.86
1984	2423.0	2395.1	2453.1	16.82
1985	2422.8	2393.0	2470.8	22.59
1986	2442.6	2406.9	2499.5	28.32

PART B: BASE-CASE DEVIATIONS

YEAR	MEAN	MINIMUM	MAXIMUM	STD. DEV.
1983	9.58	8.47	11.08	0.692
1984	8.18	6.93	9.52	0.751
1985	4.75	3.46	6.82	0.976
1986	2.38	0.89	4.77	1.187

PART C: ANNUAL RATES OF CHANGE

YEAR	MEAN	MINIMUM	MAXIMUM	STD. DEV.
1983	14.67	13.51	16.23	0.725
1984	3.04	2.79	3.47	0.190
1985	-0.01	-0.75	0.73	0.418
1986	0.81	0.33	1.38	0.309

Figure 9.7 Box Plots of Base-Case Deviations for Real PCE

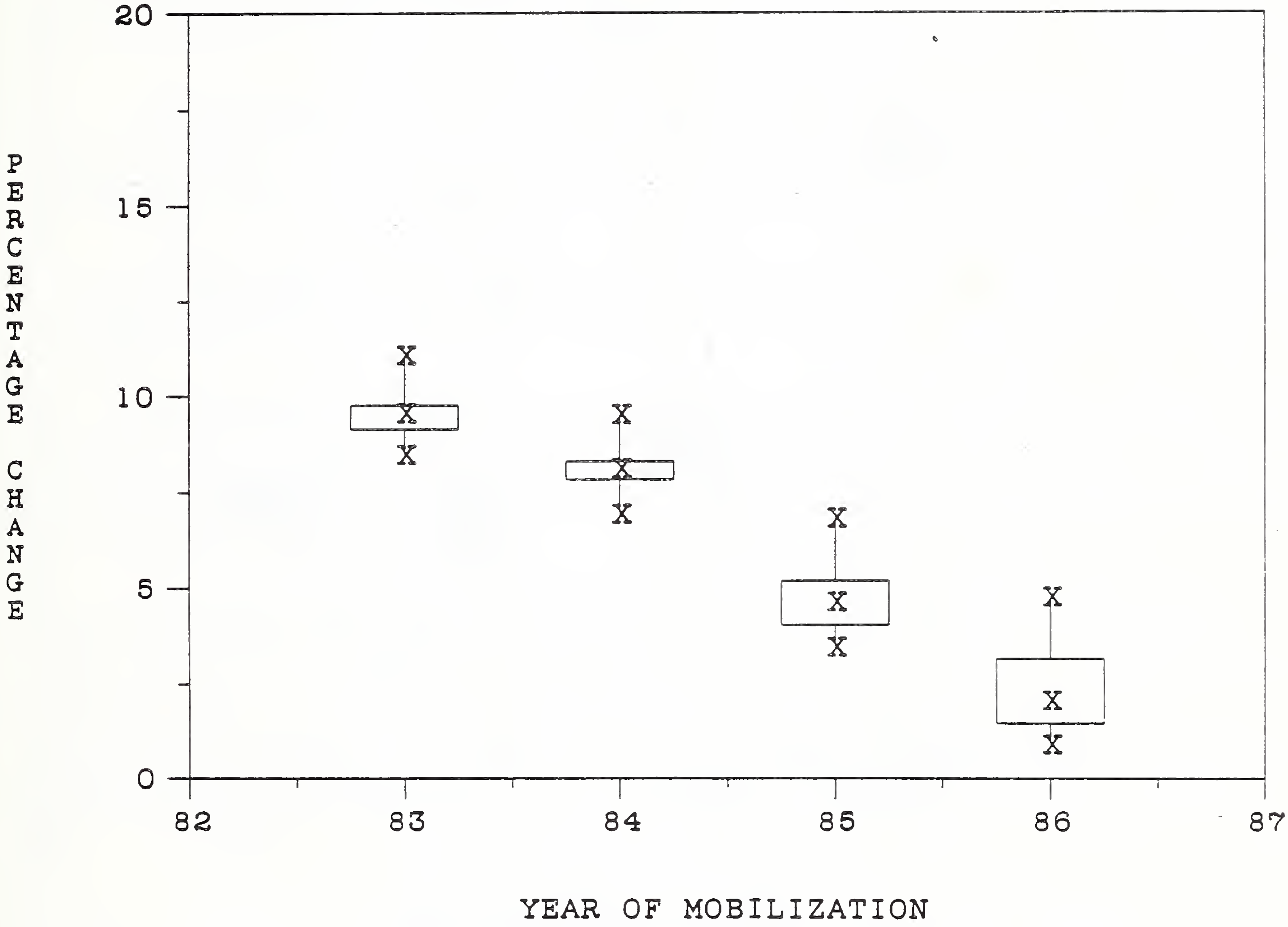
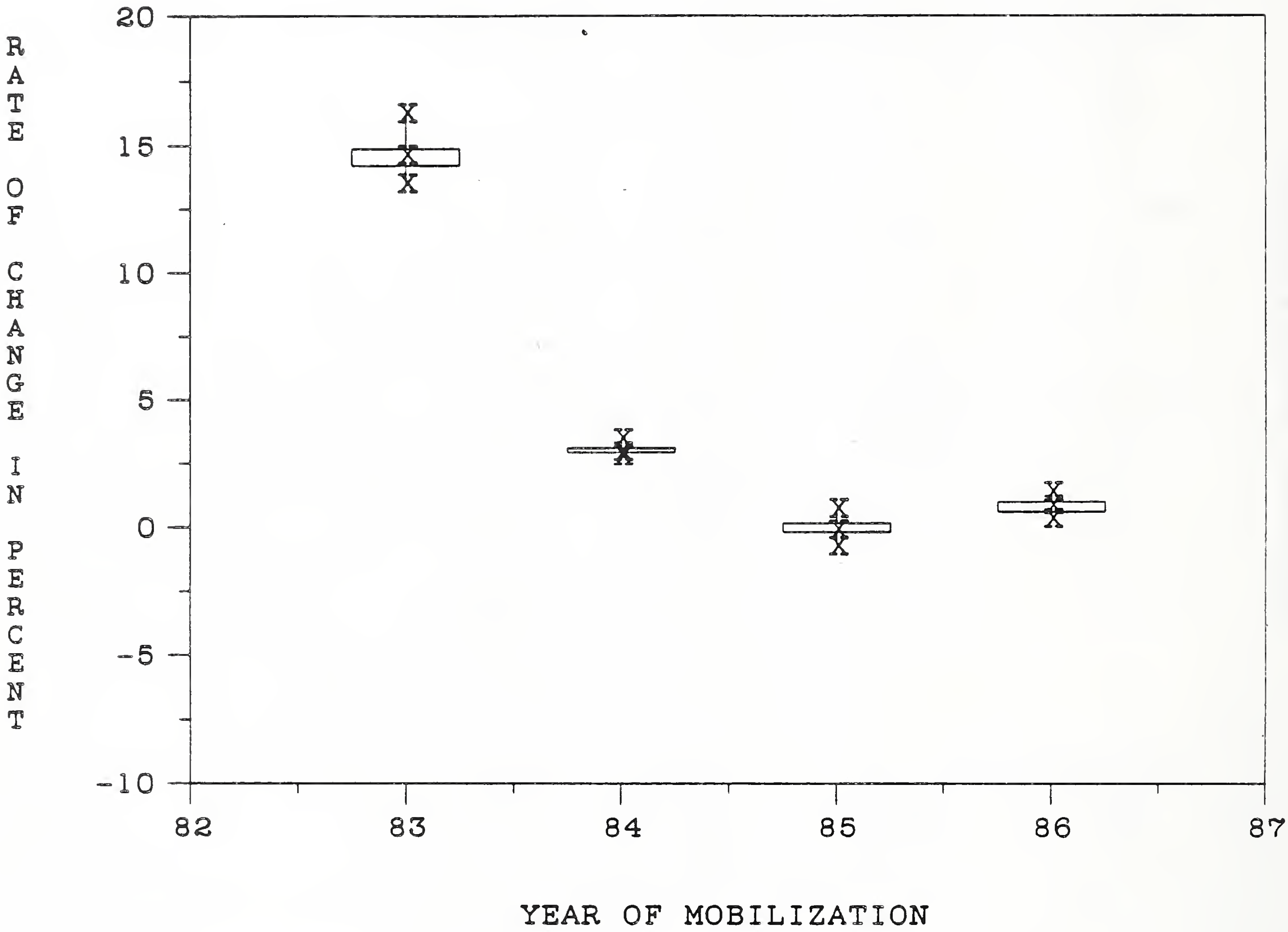


Figure 9.8 Box Plots of Annual Rates of Change for Real PCE



As was the case for real PCE, the early gains in investment due to mobilization are narrowing by 1985. Figure 9.11 differs from Figure 9.7 in that base-case deviations for real investment appear to stabilize at around 7 percent.

Figure 9.12 illustrates the importance of the business cycle. Due to the combined effects of the accelerator principle[1] and the potential for crowding out due to deficit financing, the rate of change in real investment is quite volatile. Part C of Table 9.6 shows how volatile investment spending is during the period of mobilization. After increasing by almost 41 percent in 1983, the rate of change in real investment drops to slightly under 21 percent in 1984; it then turns sharply negative to -8 percent in 1985. Investment spending then increases in 1986, although the level is still less than at its peak in 1984.

Capital Services

The wide swings in investment experienced during the mobilization lead one to conjecture about their impact on capital services. Recall that capital services are a function of the level of the capital stock at the beginning of each year and the "efficiency" with which that stock can be utilized.

Figure 9.13 illustrates that, even though investment is quite volatile, capital services increase steadily. By 1985, capital services appear to be changing according to the same long-term trend that underlies the base-case simulation.

The pattern of tapering off shown in Figure 9.13 is more pronounced in Figure 9.14. In particular, after significant increases in capital services experienced between 1983 and 1985, the change is quite modest in 1986. Reference to Part A of Table 9.7 demonstrates the degree of overlap for capital services in 1985 and 1986.

From Figure 9.13, it was clear that capital services exceeded those under the base-case simulation. It is now important to determine if these increases are significant. Reference to Figure 9.15 and Part B of Table 9.7 indicates that except for 1983, the mobilization level of capital services is significantly higher than in the base-case simulation. Thus investment volatility in the war-time economy and increased shifts, which produce increased wear and tear on the entire stock, is not sufficient to reduce the "productive flow" of services from the capital stock.

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[1] The accelerator principle asserts that net investment is a function of the rate of change in final output rather than the absolute level of output.

Figure 9.9 Values of Real Investment for the Base-Case Simulation, the Mobilization Baseline and the Mobilization Maxima

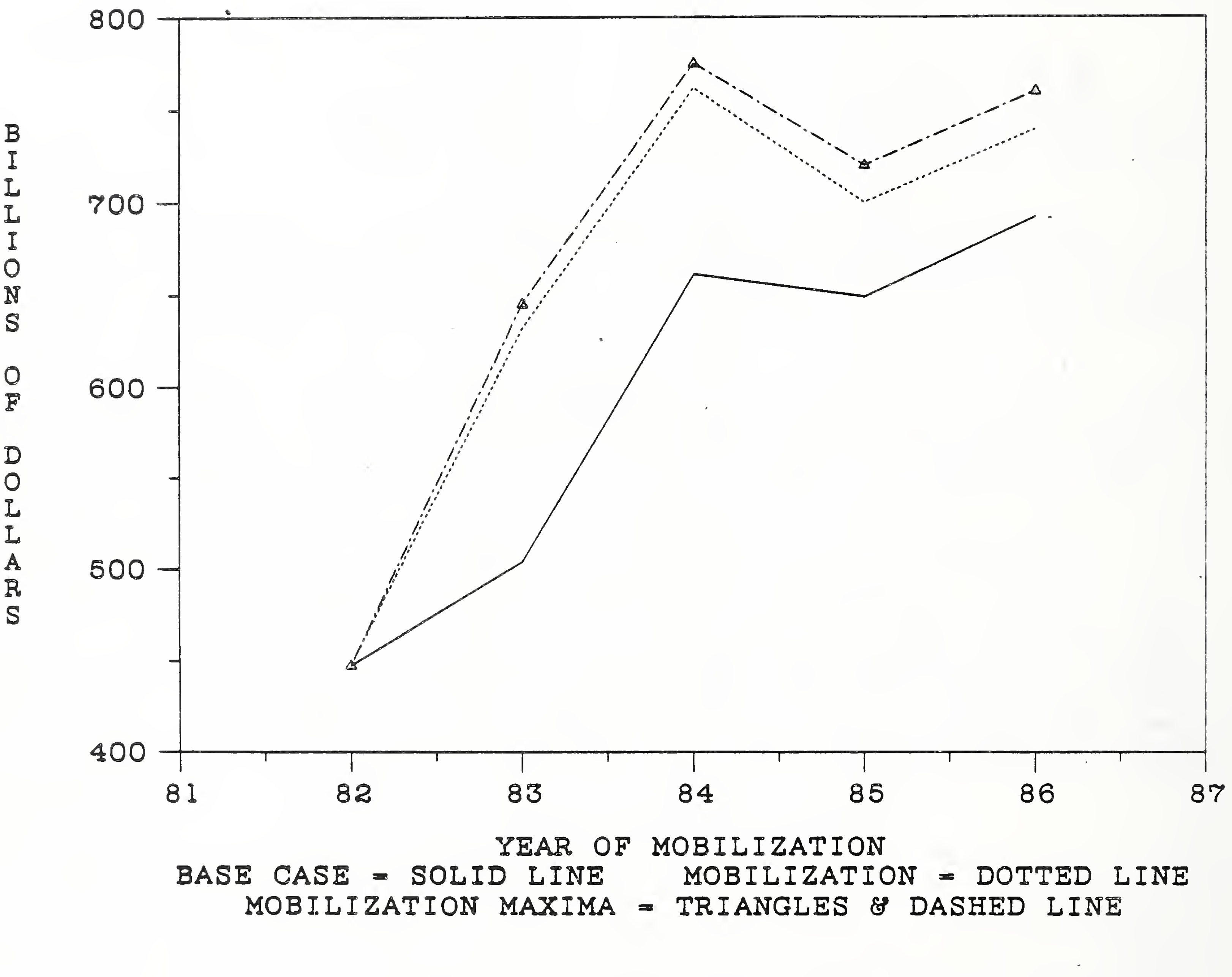


Figure 9.10 Box Plots of Mobilization Values for Real Investment

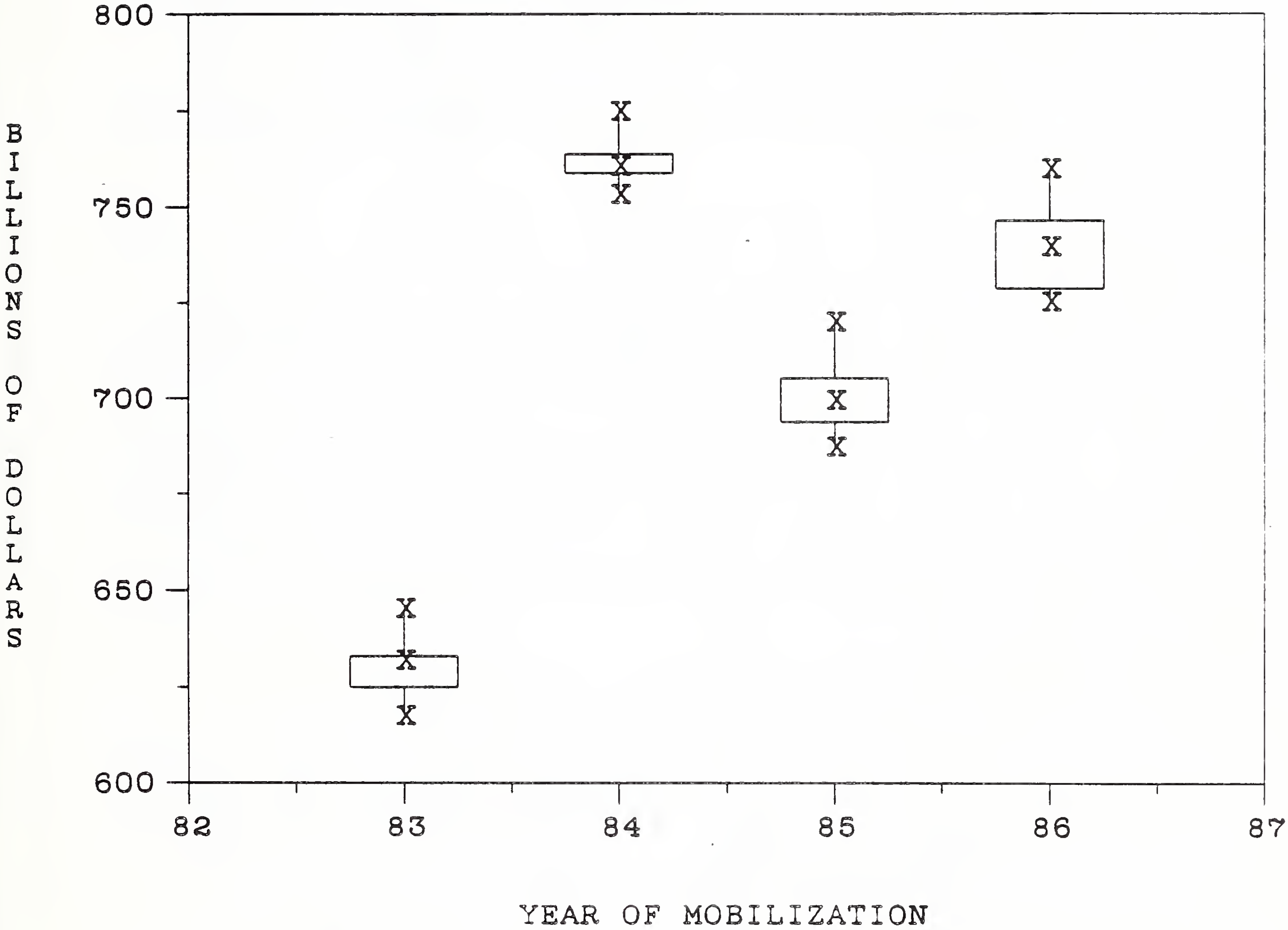


Table 9.6 Summary Statistics for Real Investment

PART A: MOBILIZATION VALUES

YEAR	MEAN	MINIMUM	MAXIMUM	STD. DEV.
1983	629.8	617.6	645.1	7.62
1984	761.4	753.4	775.0	5.91
1985	700.1	687.1	720.1	9.83
1986	739.1	725.3	759.9	11.95

PART B: BASE-CASE DEVIATIONS

YEAR	MEAN	MINIMUM	MAXIMUM	STD. DEV.
1983	25.12	22.68	28.15	1.515
1984	15.14	13.92	17.20	0.894
1985	7.87	5.88	10.95	1.514
1986	6.75	4.75	9.74	1.726

PART C: ANNUAL RATES OF CHANGE

YEAR	MEAN	MINIMUM	MAXIMUM	STD. DEV.
1983	40.81	38.07	44.23	1.705
1984	20.90	20.02	22.13	0.740
1985	-8.06	-8.79	-7.09	0.629
1986	5.58	4.67	6.39	0.489

Figure 9.11 Box Plots of Base-Case Deviations for Real Investment

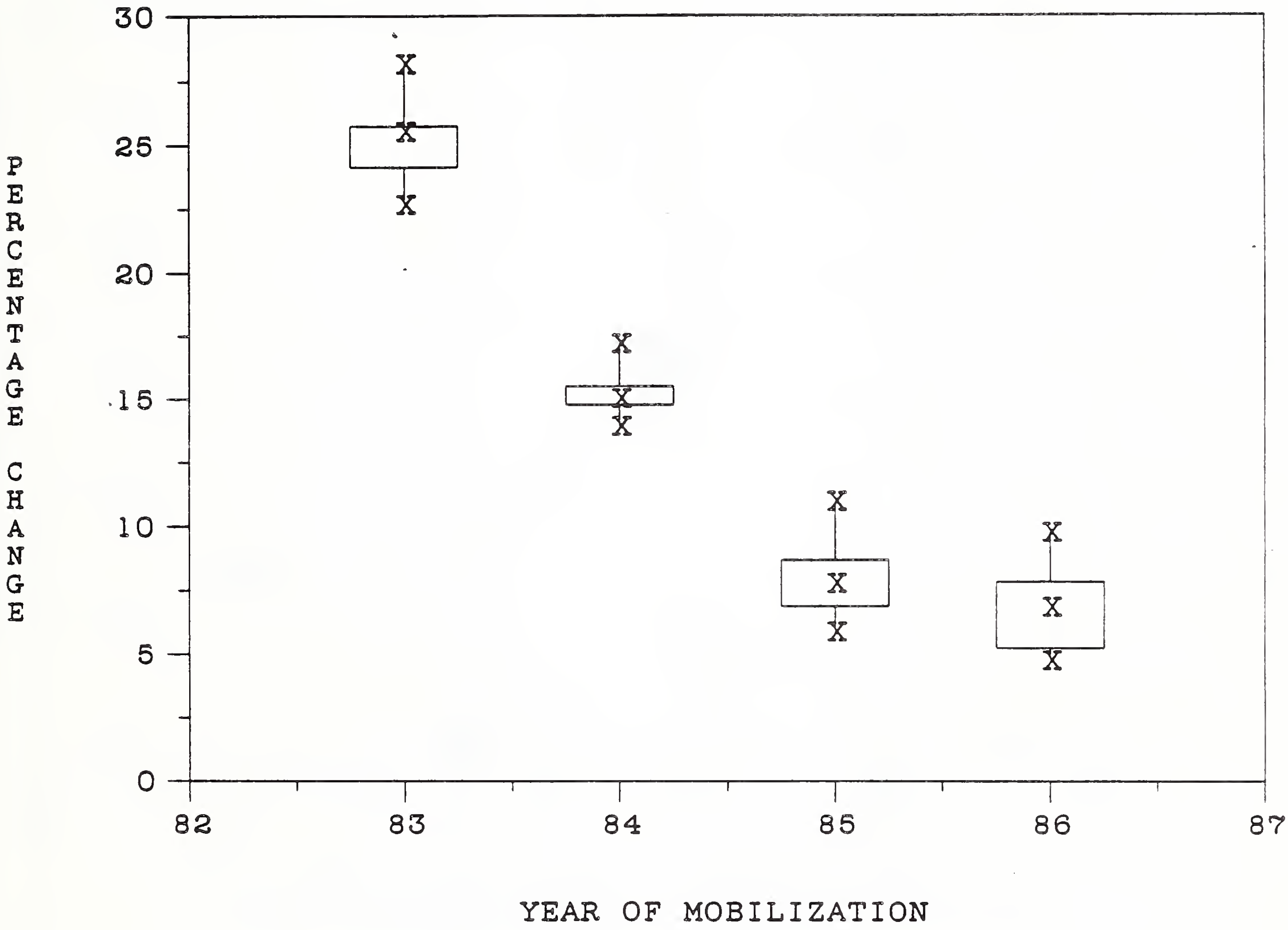


Figure 9.12 Box Plots of Annual Rates of Change for Real Investment

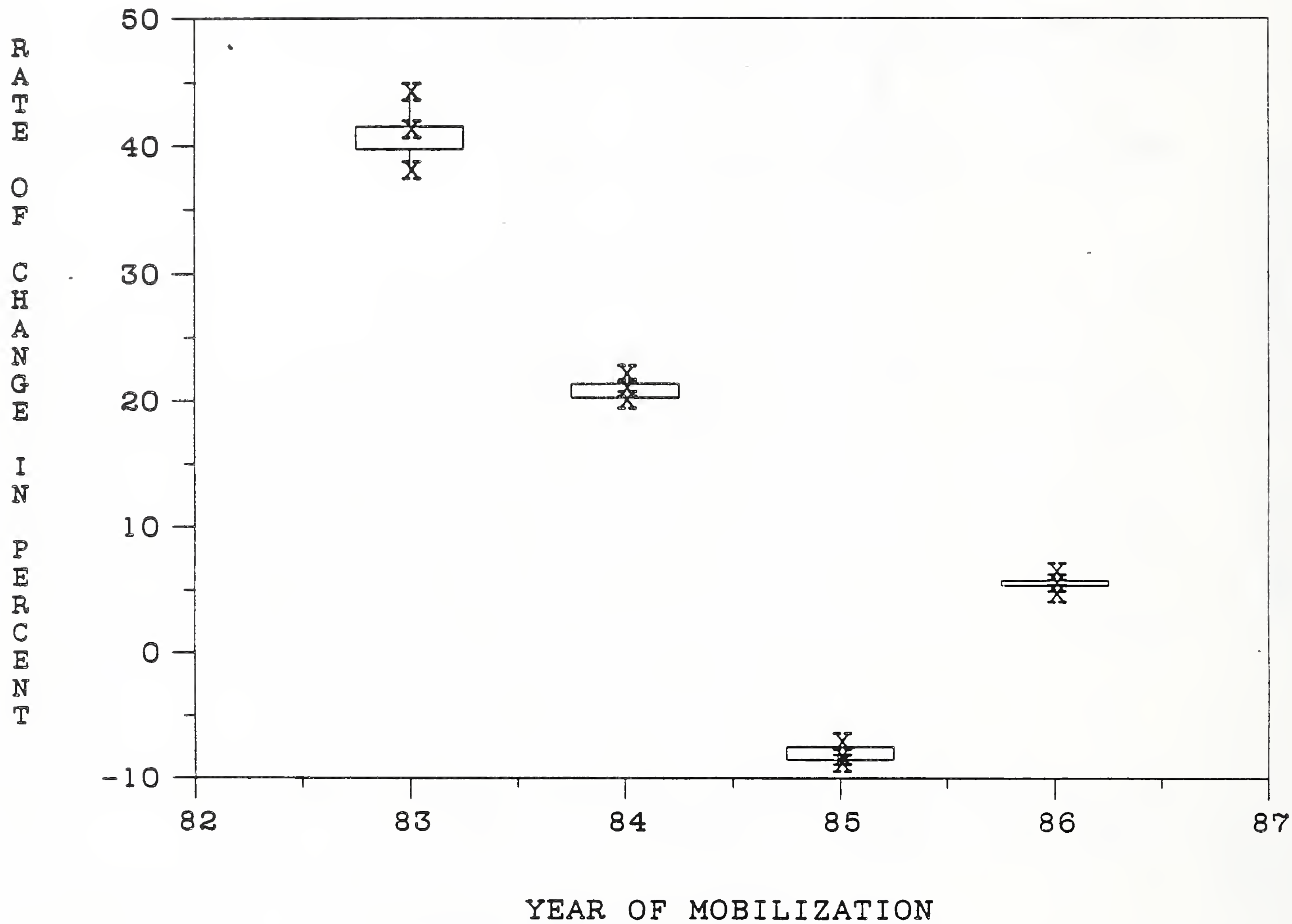


Figure 9.13 Values of Capital Services for the Base-Case Simulation, the Mobilization Baseline and the Mobilization Maxima

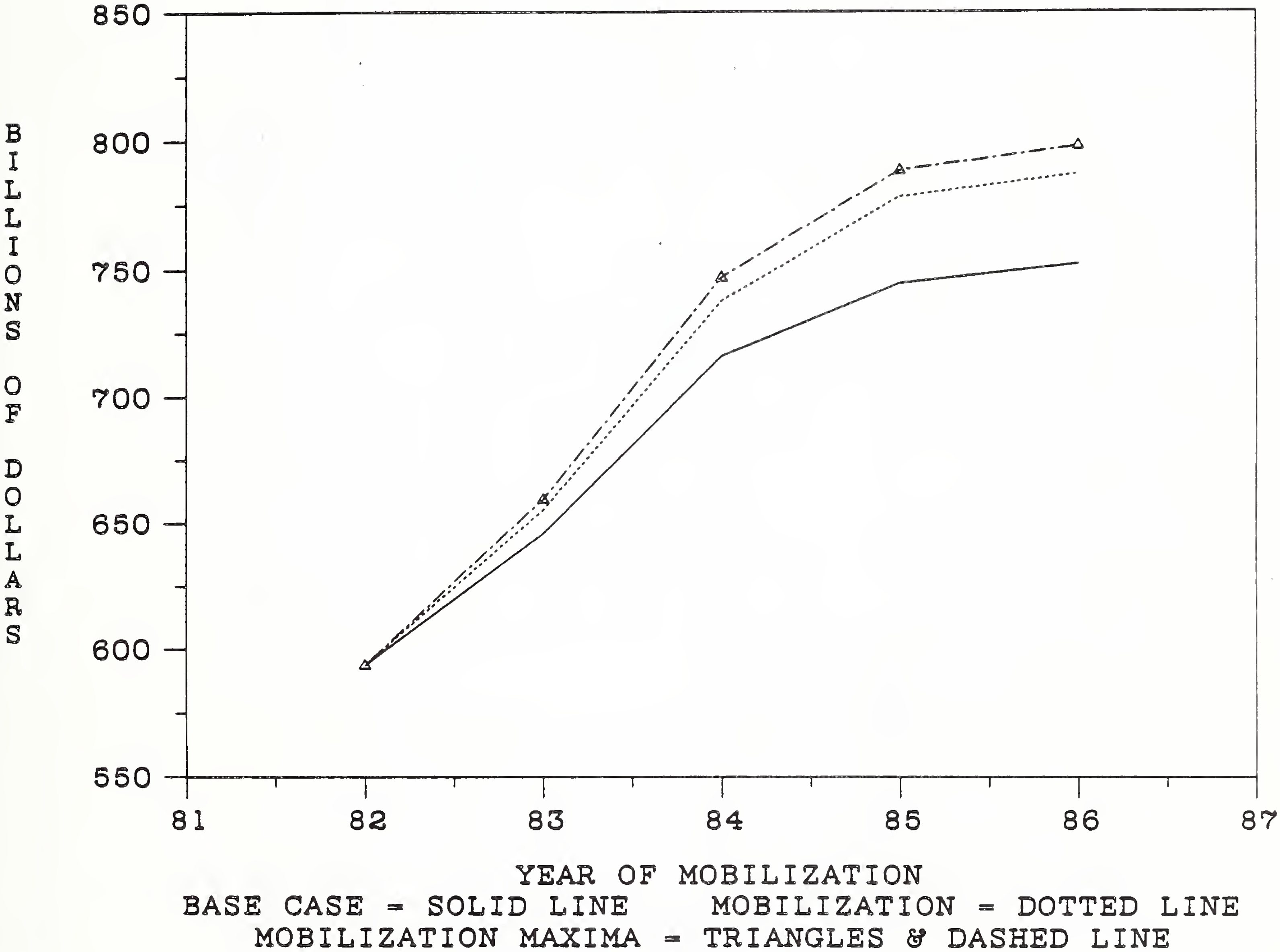


Figure 9.14 Box Plots of Mobilization Values for Capital Services

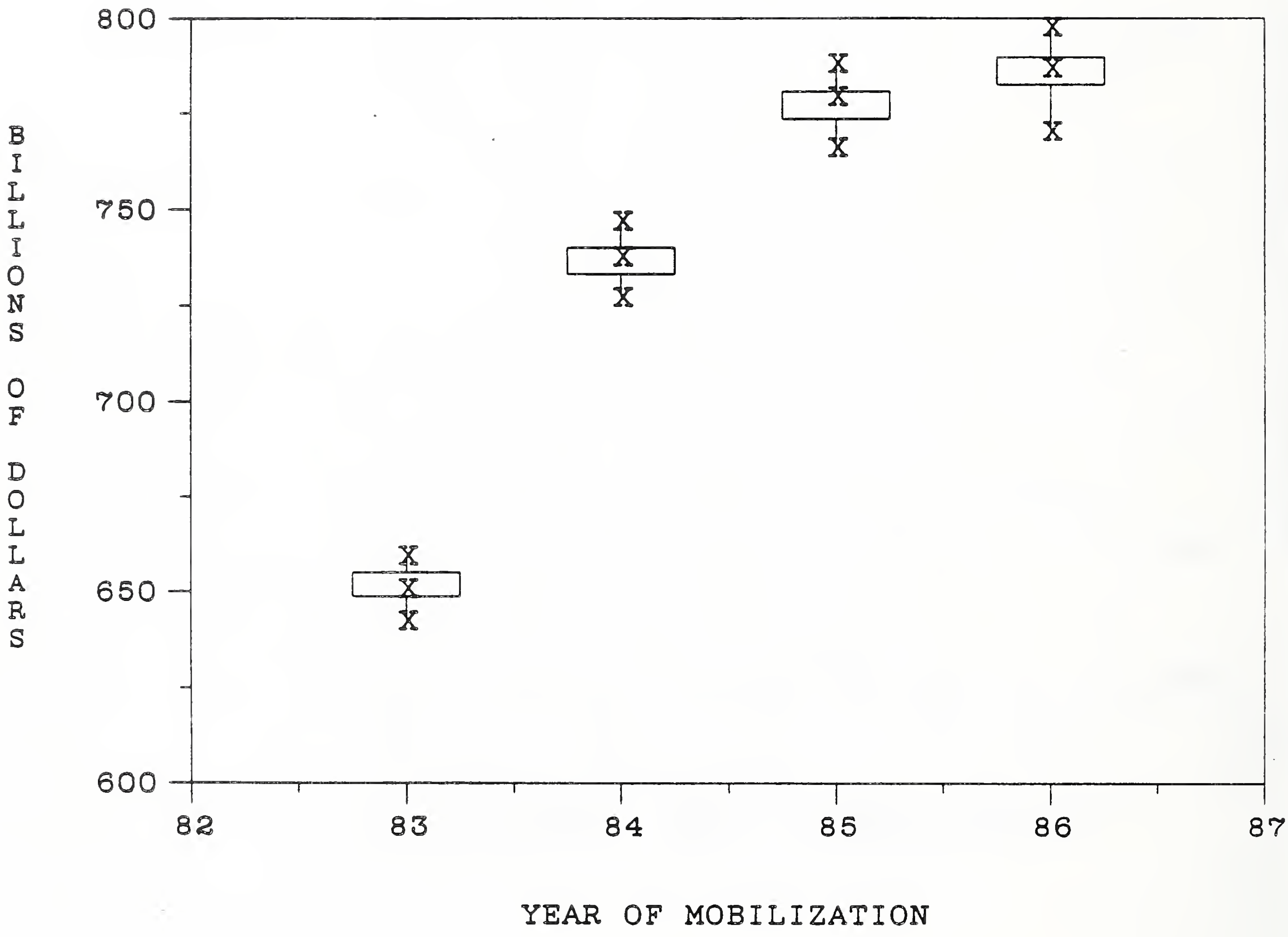


Table 9.7 Summary Statistics for Capital Services

PART A: MOBILIZATION VALUES

YEAR	MEAN	MINIMUM	MAXIMUM	STD. DEV.
1983	651.9	642.3	659.3	5.41
1984	737.0	727.2	746.9	5.64
1985	777.4	766.1	788.1	6.47
1986	785.4	770.3	797.6	8.09

PART B: BASE-CASE DEVIATIONS

YEAR	MEAN	MINIMUM	MAXIMUM	STD. DEV.
1983	0.95	-0.54	2.09	0.838
1984	2.93	1.56	4.31	0.788
1985	4.39	2.87	5.83	0.869
1986	4.41	2.39	6.03	0.108

PART C: ANNUAL RATES OF CHANGE

YEAR	MEAN	MINIMUM	MAXIMUM	STD. DEV.
1983	9.79	8.16	11.03	0.911
1984	13.05	12.49	13.51	0.389
1985	5.48	5.17	5.93	0.191
1986	1.04	0.24	1.33	0.344

Figure 9.15 Box Plots of Base-Case Deviations for Capital Services

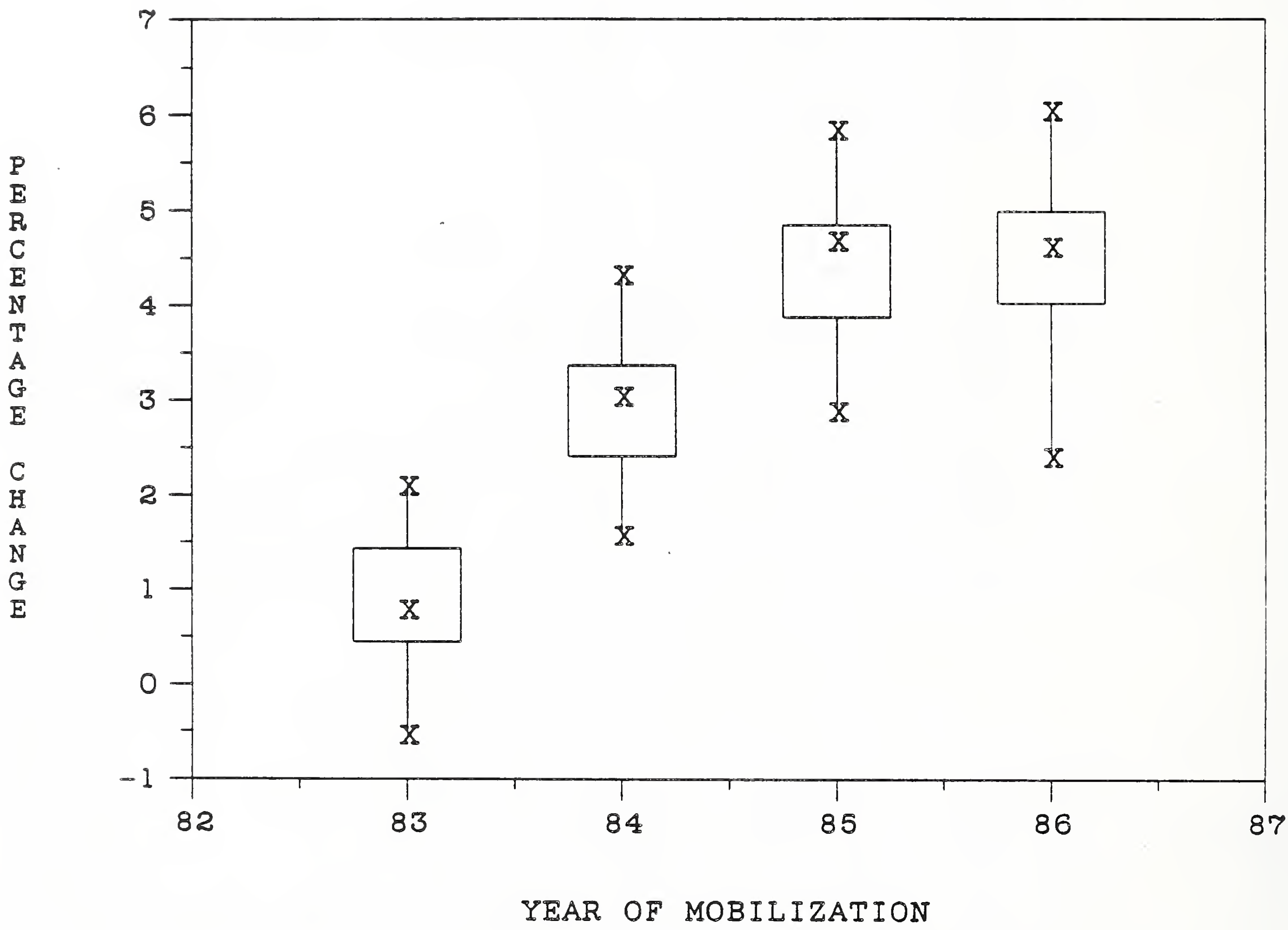
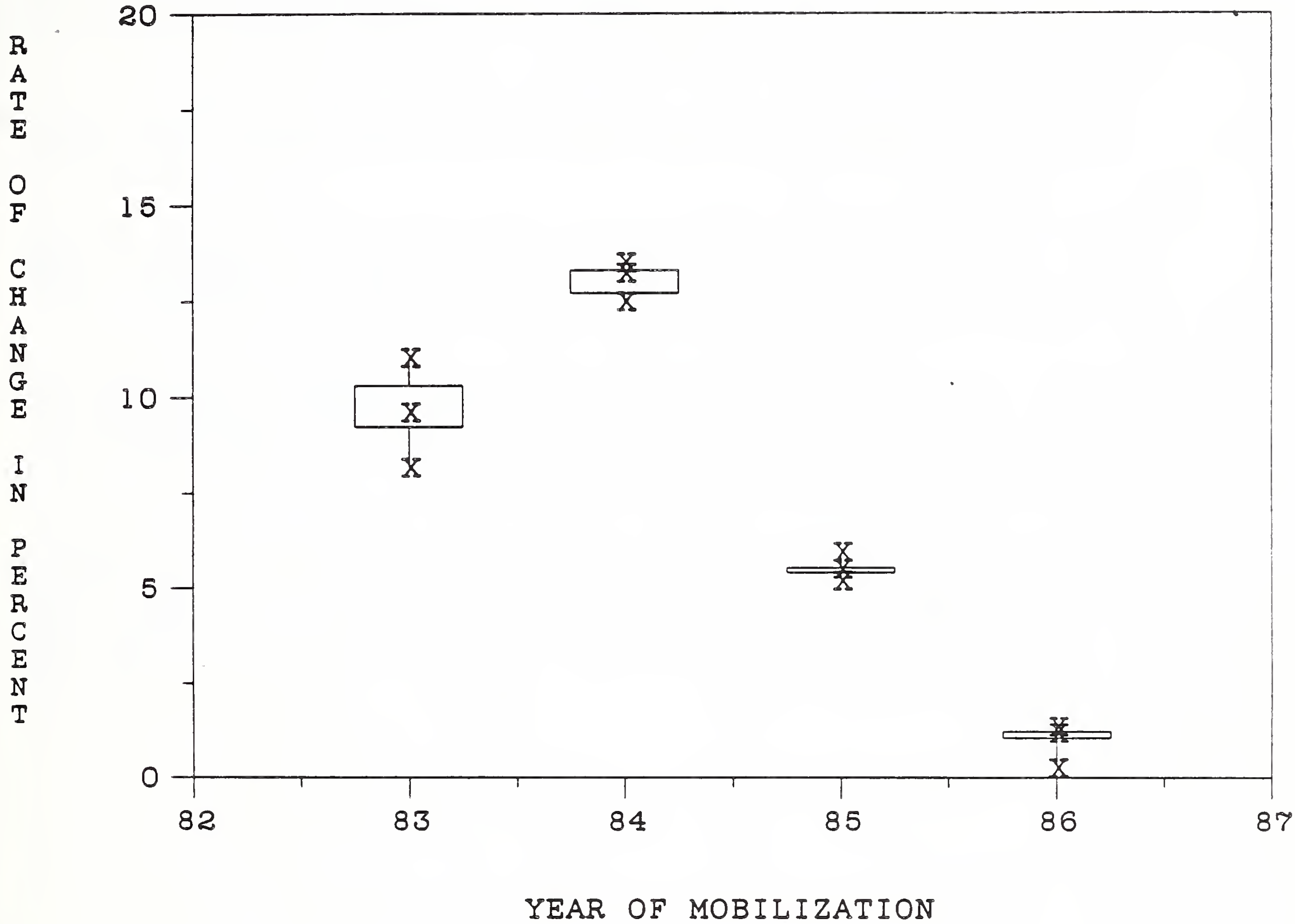


Figure 9.16 Box Plots of Annual Rates of Change for Capital Services



Since capital services are based on the quantity of capital stock available at the beginning of the year, the largest annual rate of change is experienced in 1984.[1] The rate of change in capital services then drops markedly due in part to investment volatility and the high rates of depreciation included to reflect wear and tear on the capital stock. Part C of Table 9.7 provides a tabular summary of the data shown in the box plots.

Quantity of Energy Delivered

Mobilization results in a significant increase in the demand for energy. The results of the structured sensitivity analysis indicated major increases for each type of energy (coal, electricity, natural gas, petroleum) treated by the model. Consequently, it was decided to focus on a summary measure, the sum total quantity of energy delivered, total energy.

Figure 9.17 illustrates how the quantity of total energy increases from just under 50 Quads to in excess of 70 Quads. After the initial surge, total energy delivered increases only slightly.

Due to the reduced range on the vertical axis in Figure 9.18, it is easier to see the trend in the quantity of energy delivered. As was the case for real GNP, total energy delivered increases sharply between 1983 and 1984 and then slackens. This trend is summarized in tabular form in Part A Table 9.8.

The base-case deviations for total energy, shown in Figure 9.19, follow a similar trend. Part B of Table 9.8 indicates that the trend of increasing quantities delivered in the first three years is likely to be significant while that in the final year only borders on significance.

The annual rate of change in total energy delivered, shown in Figure 9.20, follows the trend seen in Figure 9.17. After an initial surge, where the rate of increase approached 50 percent, the annual rate of increase settles into a tight band which is less than 5 percent. Part C of Table 9.8 documents the more than 10-fold decrease in the annual rate of change between 1983 and 1984 through 1986.

[1] Recall that the largest rate of change for investment was in 1983. Consequently, capital put in place through investment in 1983 is included in the quantity of capital stock available at the beginning of 1984.

Table 9.8 Summary Statistics for Total Energy

PART A: MOBILIZATION VALUES

YEAR	MEAN	MINIMUM	MAXIMUM	STD. DEV.
1983	71.89	71.62	72.18	0.183
1984	75.00	74.65	75.39	0.223
1985	75.57	75.16	75.94	0.258
1986	76.90	76.48	77.33	0.312

PART B: BASE-CASE DEVIATIONS

YEAR	MEAN	MINIMUM	MAXIMUM	STD. DEV.
1983	42.46	41.93	43.02	0.363
1984	44.13	43.47	44.88	0.428
1985	46.62	45.83	47.33	0.500
1986	47.38	46.57	48.21	0.600

PART C: ANNUAL RATES OF CHANGE

YEAR	MEAN	MINIMUM	MAXIMUM	STD. DEV.
1983	46.57	46.03	47.15	0.373
1984	4.32	4.23	4.45	0.068
1985	0.76	0.63	0.88	0.076
1986	1.77	1.64	1.92	0.092

Figure 9.17 Values of Total Energy for the Base-Case Simulation, the Mobilization Baseline and the Mobilization Maxima

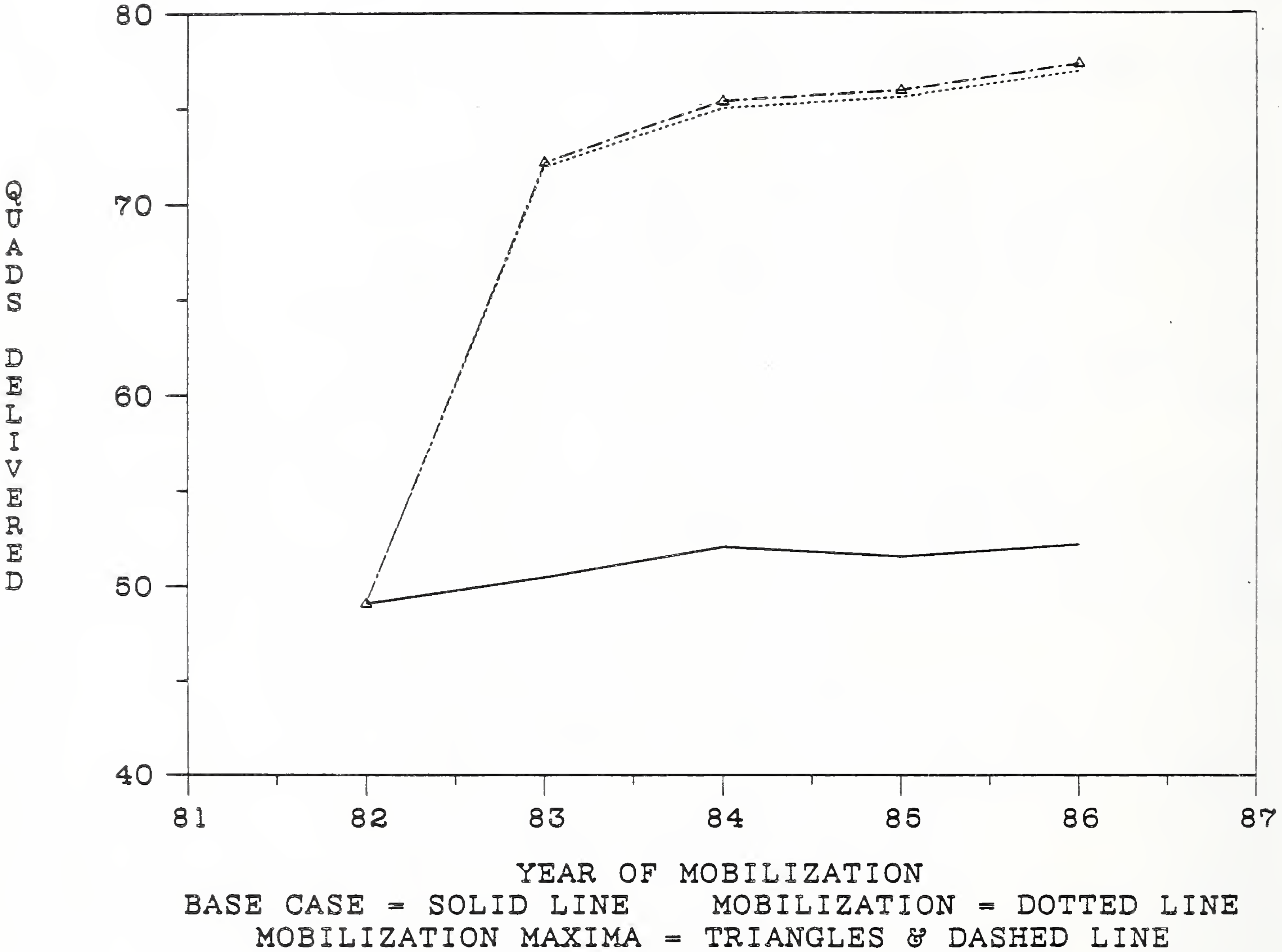


Figure 9.18 Box Plots of Mobilization Values for Total Energy

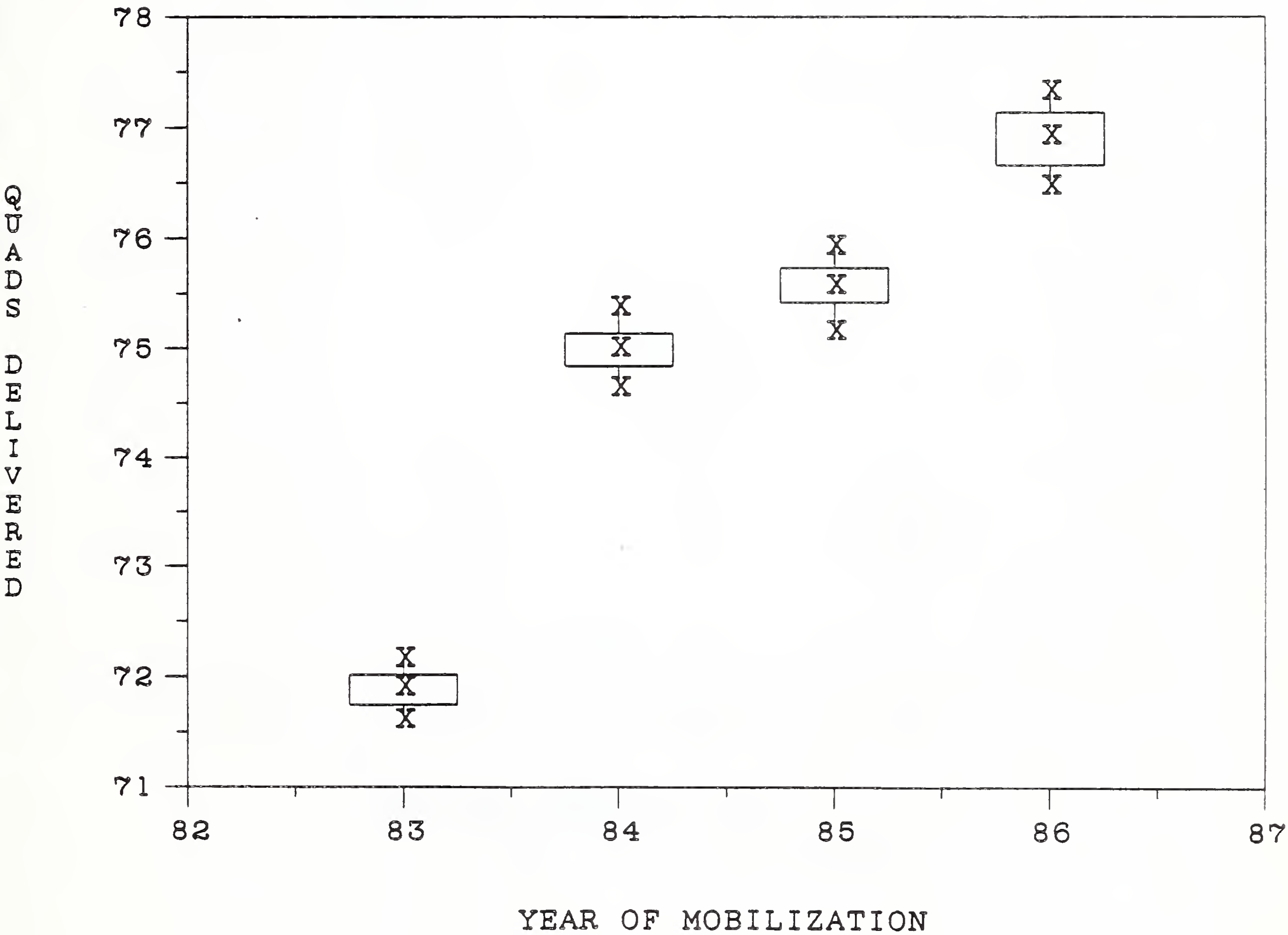


Figure 9.19 Box Plots of Base-Case Deviations for Total Energy

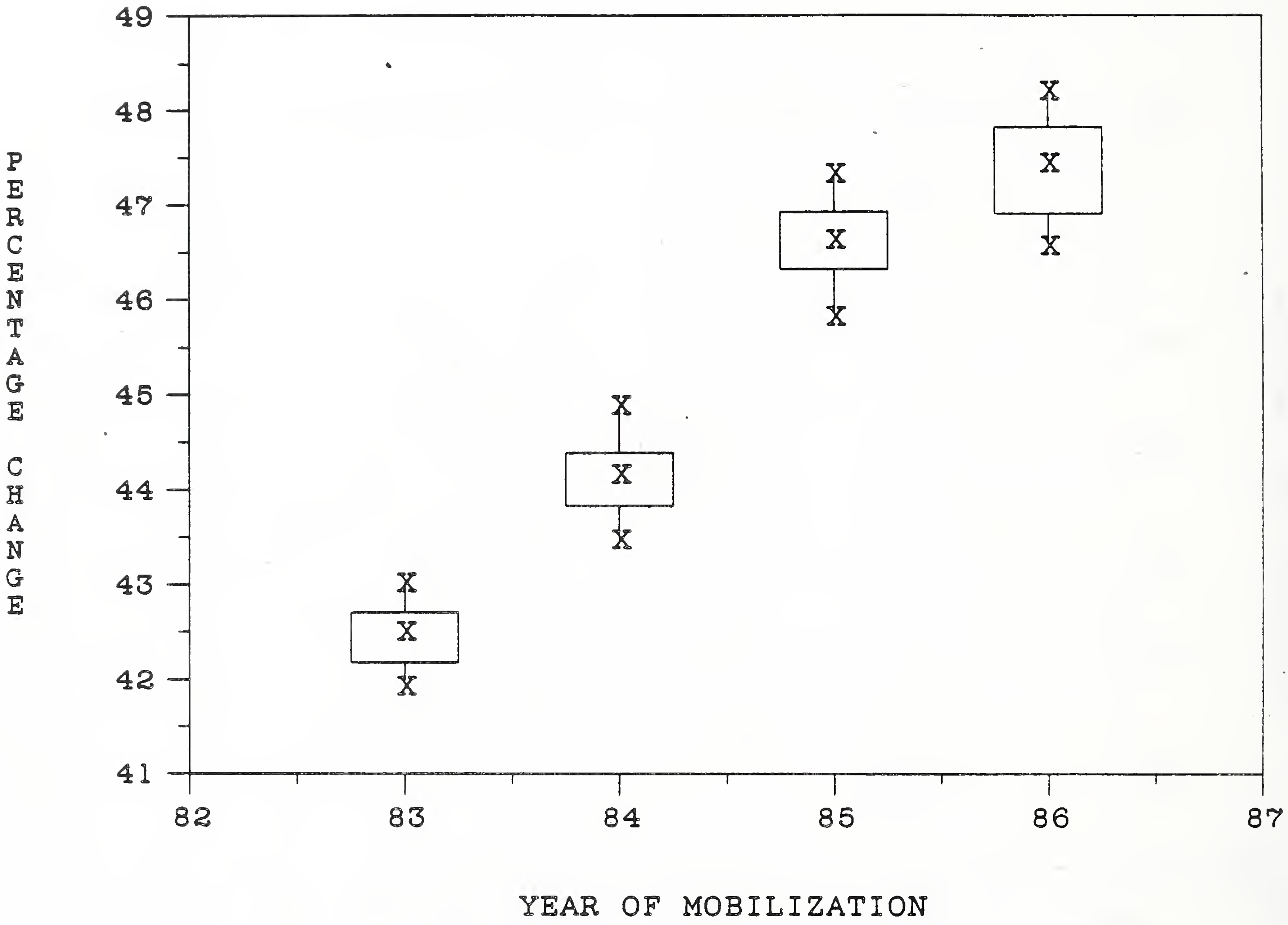
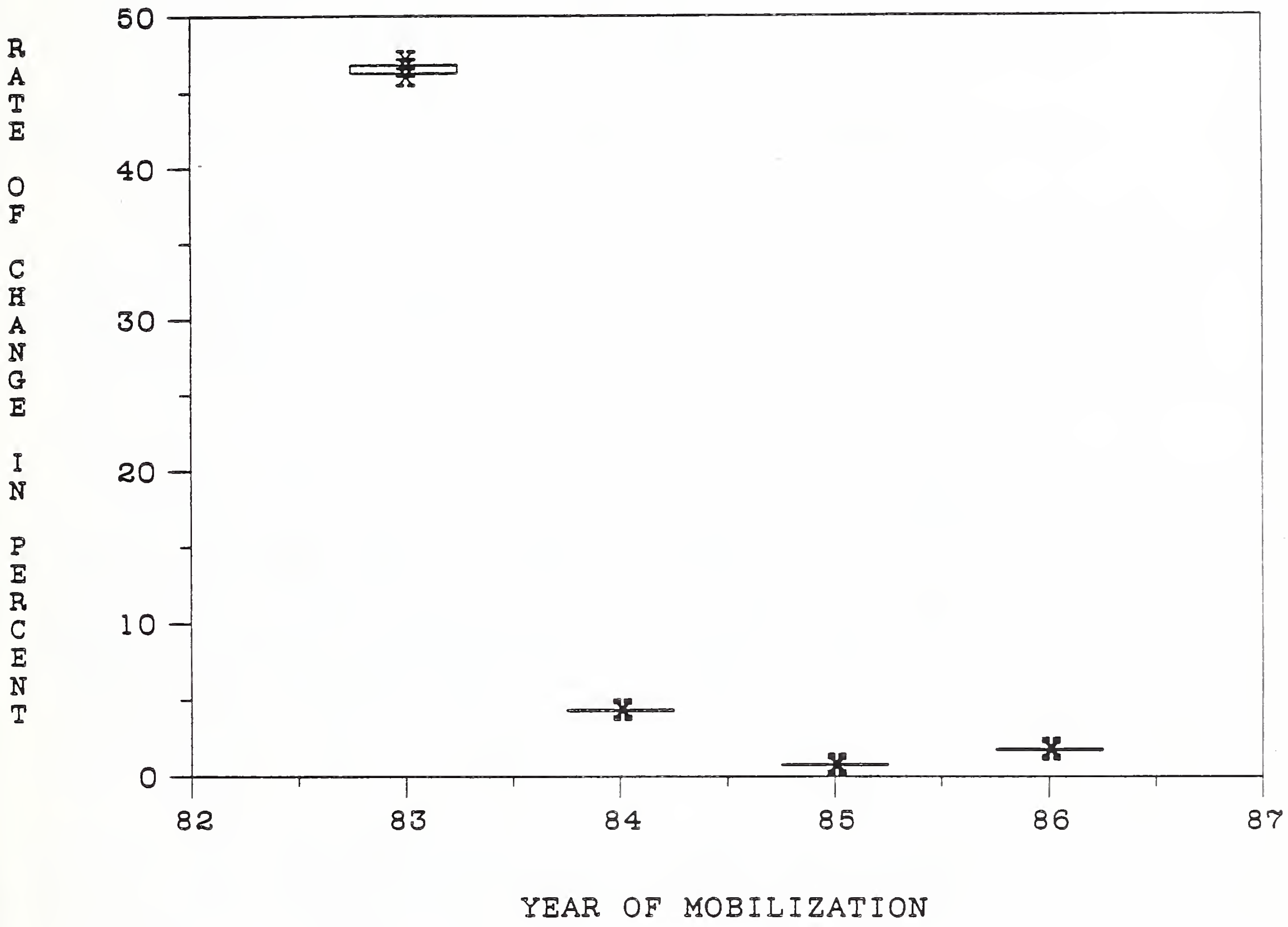


Figure 9.20 Box Plots of Annual Rates of Change for Total Energy



10 SUMMARY OF MAJOR FINDINGS

This report developed a set of generic guidelines which may be used to evaluate emergency management models and data bases. In order to provide both an explicit statement of the evaluation methodology and a step-by-step procedure for implementing it, the report was divided into two parts. The basic problem was stated in Chapter 1 where a three-phased procedure was outlined which focused on:

(1) obtaining a clear and comprehensive statement of user requirements and objectives pertaining to the application of the model;

(2) generating appropriate information about the model design and performance pertaining to user requirements; and

(3) evaluating model attributes and properties according to predetermined criteria of performance required by the user.

The "analytical techniques" associated with the second phase of the procedure form the core of the generic model/data base evaluation guidelines; they are described in Part I of the report. The stages of descriptive analysis, program verification and analysis, data audit, and sensitivity analysis provide the pool of information which drives the evaluation process. If one views the guidelines as having a front end where test results are evaluated, then the analytical techniques provide the critical linkage.

The previous point may be better understood by noting that in order to determine what the user requirements are and how they translate into a test scenario, it is necessary to understand the purpose of the model and review the documentation which purports to describe the model, as implemented on the host system. These topics are the subject of Chapter 2 and Sections 3.1 and 4.1. One must also recognize that in the information development and generation phase of the evaluation, it is necessary to state which questions are to be studied and which instruments are to be used to address these questions (e.g., special data, control variables, parameters). Answers to these questions take the evaluator deeper into the topics discussed in Chapter 3, program verification and analysis.

The data audit, Chapter 4, serves to firm up the test scenario by studying the model-data interface and the analysis of file computerization and accessibility. Specialized statistical techniques are also used to characterize the variability of the input data. This step, in conjunction with a review of the documentation for the data base, provides guidance in designing the sensitivity analysis.

A structured sensitivity analysis is the culmination of the earlier stages in the evaluation process. The specialized techniques for performing a sensitivity analysis discussed in Section 5.2 seek to develop relationships between input uncertainties and the variability of the model's output, to find areas where the model's output changes drastically (e.g., due to instabilities), or to exploit unique capabilities of the model. A major goal in performing a sensitivity analysis is to generate the critical pieces of information for those acceptance tests which focus on quantitative characteristics.

How the process of information development and generation is incorporated into a generic model/data base evaluation procedure is illustrated in Part II of the report. The Dynamic General Equilibrium Model (DGEM) is used as a test vehicle for the generic evaluation guidelines. DGEM was selected for evaluation primarily for its unique approach to modeling emergency situations. The availability of documentation was also a major factor. We wish to alert the reader to the importance of documentation in any model evaluation effort because it is the principal means through which performance against user requirements can be measured.

The analysis of the U.S. economy during a military mobilization is used to illustrate how the evaluation procedure may be applied to DGEM. This approach was taken for two reasons. First, a mobilization represents a major perturbation about the "business as usual" base-case simulation. Consequently, any weaknesses of the model (e.g., instabilities, implausible results, etc.) should be revealed by such a perturbation. Second, a mobilization requires an explicit treatment of the joint interactions of several factors (e.g., international trade, the business cycle, available capacity, investment, etc.).

The formulation of the mobilization scenario used in the evaluation of DGEM was a two-stage process. In the first, a mobilization baseline was constructed which made explicit the perturbations about the business as usual values in the DGEM data base. The mobilization baseline also provided a point of reference for how the joint interactions of these perturbations affected the path of the national economy. In the second, six key variables were varied in combination subject to an experimental design. This enabled us to explore in detail certain patterns which were uncovered in the mobilization baseline.

The previous discussion and material presented in Chapter 9 demonstrates that there are at least four reasons why DGEM can be a useful tool for analyzing the economic impacts of a military mobilization. First and foremost, DGEM was designed to deal with the demand surges and resource constraints which are expected during the transition from a peace-time to a war-time economy. Specifically, DGEM explicitly addresses factors which affect both demand and supply on an annual basis up through the year 2000. Second, the TUTOR provides the user with a set of step-by-step instructions for incorporating information on Defense and other government expenditures as well as economic and technical considerations which specify how the economy mobilizes. Third, from a review of the documentation, it became clear that much care went into the design, development and testing of the model. Furthermore, the model's documentation is quite complete and should be sufficient to: (1) set it up on the host system; (2) execute a base-case simulation; (3) interpret the results of the base-case simulation; (4) create, run, and interpret user-specified simulations. Finally, the DGEM source code has been made available to a number of users, enabling them to explore the major linkages within the model as well as trace the flow of calculations for particular variables of interest.

In Chapter 6, a set of four user requirements were postulated. For ease of reference, each requirement is summarized briefly; a point-by-point review is then given. Requirement 1 focuses on model usage (i.e., the operational model). Requirement 2 addresses the clarity and completeness of the documentation for the conceptual and mathematical models. Requirement 3 focuses on the relationships between the National Income and Product Accounts (NIPA) and the model's output. Requirement 4 is concerned with a variety of economic-technical attributes.

In the discussion which follows, material is presented which compares critically the information generated in the model evaluation process against user requirements. This comparison enables us to conclude that DGEM is both an appropriate and useful model for analyzing the types of problems anticipated during a military mobilization.

Requirement 1

The model must have documentation sufficient to enable an analyst to:

(a) set it up on the host system;
(b) execute a base-case simulation;
(c) interpret the results of the base-case simulation; and
(d) create, run, and interpret user-specified simulations.

Narrative

Item a: The documentation for DGEM is quite complete and should be sufficient for an analyst to set it up on the host system.

Item b: The TUTOR provides a convenient and essentially "fool proof" means for specifying and executing a base-case simulation.

Item c: Several parts of the DGEM documentation provide detailed descriptions of the base-case simulation. Furthermore, these descriptions provide valuable insights into the DGEM analysis framework, which should be helpful to users in specifying their own simulations.

Item d: The DGEM documentation and the structure of the TUTOR are sufficient to enable an analyst to create, run, and interpret a user-specified simulation. The TUTOR, through its nested set of menus, facilitates the process of specifying a simulation. In many cases, questions posed to the analyst by the TUTOR provide reference to the values of key variables contained in the base-case simulation. Consequently, the analyst may specify major portions of the desired simulation via a set of "perturbations" about the base-case simulation.

Requirement 2

The structure of the model should be clearly documented. This requirement includes information on the model's:

(a) policy context;
(b) objectives;
(c) exogenous and endogenous variables;
(d) equation structure; and
(e) data base(s).

To the extent feasible, the user should be assured that the forecast values of the "base-case" simulation have been compared to historically achieved values. Any major discrepancies should be documented and, if possible, explained.

Narrative

Item a: DGEM provides the potential user with significant latitude for specifying policy options and for evaluating their economic merits. The TUTOR is especially helpful in defining how the model can address mobilization-oriented policies.

Item b: It is anticipated that model users will exhibit a wide range of objectives. The documentation (especially the User's Guide) and the TUTOR should be sufficient for defining the user's analytical objectives and for translating them into a runstream for executing the model. At an aggregate level, the TUTOR alone may be sufficient to specify an approach for evaluating the economic impacts of both the increased defense purchases and resource constraints (e.g., supply interruptions) anticipated under a military mobilization. Some sectoral information is also available. For example, for any of the 36 sectors treated within the DGEM analysis framework, the analyst can constrain the inputs to or outputs from that sector. Such an analytical approach can be useful in identifying bottlenecks or assigning priorities to certain industries for a particular set of inputs.

Item c: Information on the model's exogenous and endogenous variables is presented in 36 DGEM: The Dynamic General Equilibrium Simulation Model. This information has been expanded, reflecting the code changes described earlier as well as the incorporation of the TUTOR, and is recorded in Appendix E.

Item d: The equation structure of DGEM is well documented. The report, 36DGEM: The Dynamic General Equilibrium Simulation Model, includes explicit mathematical descriptions of: (1) submodels of producer behavior, one for each of the 36 domestic producing sectors; (2) a model of consumer behavior; (3) balance equations covering physical flows through the interindustry system equating demand and supply quantities of each good or service transacted; (4) market balance equations equating value of expenditure and receipts for each good or service transacted; (5) financial identities aggregating value flows into aggregate income, financial and economic accounts; and (6) government and rest of the world accounts.

Item e: The DGEM database consists of 19,327 entries for each of 43 years (i.e., 1958 through the year 2000). Of the 19,327 entries for each year 5,903 are endogenous variables, 1,643 are exogenous variables, and 11,781 are coefficients. The estimation of the model over the historical period (i.e., 1958 to 1974) used a database constructed by Jack Faucett and Associates. In Chapter 8, three sets of base-case simulations were reviewed; they were: (1) model performance over the historical period (i.e., simulations between 1959 and 1974); (2) model performance between 1975 and 1981, when published data on certain key variables was available; and (3) the base-case projections (i.e., simulations between 1982 and year 2000). In evaluating DGEM's performance between 1975 and 1981, one must recognize that while many variables were aligned to observed values, many were not. In most cases, the simulated values for these compare favorably with information developed from published sources. For example, comparisons between figures published by the Department of Labor and values from the database for 1974 and 1980 showed close agreement in the relative importance of each industry and the changing nature of that importance over time.

Requirement 3

The model must be cross referenced to the National Income and Product Accounts (NIPA). This minimum requirement provides a set of control totals, which may be used to disaggregate the model's output to address sector specific issues. Furthermore, it is desirable for the model to provide information on those endogenous and exogenous variables likely to be of interest to decision makers. This information may be useful either in gaining insights regarding the "path" of the economy to a war-time footing or in preparing customized reports.

Narrative

Some of the final demand and expenditure accounts in DGEM are based on an accounting system developed by Christensen and Jorgenson. This system was specifically designed to identify and handle consistently variables involved in economic growth. Because of this, the system differs slightly from the National Income and Product Accounts (NIPA) which are the commonly used framework for economic accounting. The principal difference between the DGEM and NIPA accounting systems arises in the treatment of household sector capital. This capital comprises residential property, automobiles, and other consumer durables. Household capital is explicitly treated as capital in the household sector accounts. Purchases of consumer durables are included in investment, not in consumption, and the imputed value of services from this capital is calculated and included in consumption. This yields a system of accounts in which investment includes all additions to capital stock and in which consumption comprises only current goods and services. The NIPA system differs from DGEM in that it includes in consumption an imputation for the services from owner-occupied residential structures but not those from other forms of consumer durables. Consequently, a bridge is used to map between the two accounting systems. The bridge comprises a set of stochastic equations and identities that permit the DGEM final demand aggregates to be expressed in NIPA terms. The stochastic equations map model variables such as real consumption, real investment, price of consumption, and price of investment into the corresponding NIPA variables. The identities then aggregate expenditure and output into gross national product (GNP), real GNP, and the remaining aggregates in the standard national income accounts.

Requirement 4

The model must incorporate the following economic-technical attributes:

(a) the increasing importance of international trade over the past decade;
(b) the business cycle concept;
(c) the changing composition of the Gross National Product (GNP);
(d) the concepts of investment, capital services, depreciation, and emergency capacity;
(e) wage and price variables;
(f) both supply (e.g., capital and labor services available) and demand (e.g., military requirements) concepts;
(g) an explicit treatment of both fiscal and monetary policy;
(h) dynamic characteristics whereby production and consumption decisions in one period affect the economy in future periods; and
(i) bridges to or from key variables (e.g., from the NIPA components to specific sectors as defined by the Commerce Department's 4-digit Standardized Industrial Classification (SIC)).

Narrative

Item a: DGEM addresses foreign trade both as a part of final demand (exports) and as a source of goods and services (imports). Via the TUTOR, imports can be specified on an industry-by-industry basis; tariffs or quantitative controls are available for limiting imports. Exports can be altered industry-by-industry or the overall volume of exports can be changed by keeping the composition unaltered. Also, there are considerations for the balance of trade. The balance of trade can be unconstrained or it can be subject to limits, reflecting the constraints that normally exist.

Item b: Between 1982 and the year 2000 economic growth is projected to average just over 3 percent per year. This represents continued growth at rates less rapid than during the World War II to 1973 period but more rapid than during the 1973-1983 decade. This growth is slightly more rapid in the 1980's than in the 1990's. Economic growth tends to be uneven or cyclical rather than regular. Hence, there are cycles around the overall growth trend. A feature of many previous cycles has been the influence of federal policies, with expansionary policy in the run up to an election producing strong growth then the post-election tightening of policy leading to a recession. The correlation is not perfect but it is certainly present. Therefore, an election-related cycle is assumed to continue over the DGEM forecast period.

Item c: The different types of final demand (e.g., personal consumption expenditures, investment, and government purchases) display very different patterns over the business cycle. Government purchases are the most stable since they reflect political rather than market forces. Although government purchases may show uneven growth rates, these are not related to the business cycle and generally even work to dampen the magnitude of the cycle. Personal consumption is intermediate. Service and nondurables purchases are very stable, durable purchases are cylical, so that overall consumption volumes show only a mild cycle. Private investment is the most volatile of the main spending components. In recession years, investment growth is zero or even negative; in the recovery years, investment volumes grow much more rapidly than the rest of the economy. The composition of final demand between personal consumption expenditures, private investment and government purchases (i.e., how the output of the economy is used) is projected to show substantive change (see Table 8.5 where the composition of final demand in both current and constant dollar terms is shown).

Item d: Capital markets are modeled explicitly by DGEM. The model of capital markets within DGEM includes private saving, private investment, government borrowing, and foreign borrowing. The government deficit plays an important role in capital markets as modeled within DGEM because it represents a "firm" demand for funds in those markets. In cases where the government deficit is financed, the government claims a larger share of investible funds and tends to "crowd out" private investment. DGEM provides a model of investment which incorporates the business cycle concept with the potential for crowding out due to deficit financing. Since net investment is related to the rate of change in final output rather than the absolute level of output, the rate of change in real investment within DGEM is quite volatile. Capital services are a function of the level of the capital stock at the beginning of each year and the efficiency with which that stock can be utilized. Consequently, even though investment is quite volatile, capital services increase steadily over the mobilization period. Both the efficiency with which the capital stock can be utilized and the rate of depreciation of that stock are explicit in DGEM. This is essential for any mobilization application because it enables the model to capture cases where the existing capital stock is used more intensively (e.g., going to multiple shifts or increased utilization for existing multi-shift facilities) and consequently is subjected to greater wear and tear. Emergency capacity can be modeled indirectly by adjusting the efficiency with which the overall stock of capital is utilized. This approach results in an increased flow of capital services which supports the higher levels of output required in a mobilization situation but ignores the net additions to the overall stock of capital. In this important aspect DGEM differs from ROCS, another emergency management model currently used by FEMA and DoD (see Appendix D), which uses explicit sector-by-sector estimates of emergency capacity. Two other concerns regarding DGEM's modeling of capital markets should also be noted.[1] First, DGEM assumes all inputs (including durable plant and equipment, land and working capital) are instantaneously adjustable among firms and sectors. Consequently, there is no notion of industry-specific capital plant and equipment. This has as an implication that the production estimates from DGEM may be somewhat optimistic. Second, if the capital service price formulation used in DGEM were estimated using the theoretically appropriate ex ante cost of capital, then the new parameter and elasticity estimates could differ considerably from those now found in the DGEM data base.

Item e: Both wage and price variables are treated in the DGEM analysis framework. Household behavior is modeled through spending-saving and work-leisure decisions. Prices of each industry's output are endogenous, reflecting input prices, productivity, and input patterns. The price setting procedure of DGEM is based on the following assumptions: (1) all sectors are characterized by constant returns to scale; (2) there is perfect competition in the input and output markets; and (3) all inputs are instantaneously adjustable among firms and sectors. Given the above assumptions, it follows that economic profits are zero at each point in time for each sector and that price equals average and marginal cost. In summary, price setting takes place by setting

[1] Berndt, E. R., op cit., pp 11-6.

price equal to average cost (which in turn equals marginal cost). Prices are therefore independent of the level of demand for the product. Once these prices are set, absolute demands for outputs and inputs can then be obtained. In view of the previously stated assumptions and a non-substitution theorem put forward by Samuelson, all industry I-O coefficients are independent of the structure and distribution of final demand.[1] On the labor side, labor supply is the outcome of consumer's optimizations, while labor demand is the sum of demands from optimizations in each of the 36 producing sectors. For any given real wage rate, labor supply is determined endogenously. The number of unemployed workers (determined exogenously) is then subtracted from the labor supply to get a "net" labor supply. Real wage rates are then adjusted so that the leisure-work choice decision minus exogenous unemployment results in a net labor supply that just equals total labor demand. Since unemployment is modeled exogenously, the wage rates in DGEM are not those that clear labor markets but rather those that clear markets given exogenously set unemployment rates. One may therefore conclude that while the model has very appealing general equilibrium features, the labor market is classical in that unemployment cannot be explained.

Item f: The DGEM analysis framework is based on the application of econometric modeling to input-output analysis. Where input-output analysis assumes fixed input-output coefficients at any point in time DGEM provides for flexible input-output coefficients induced by price variations in primary inputs which are associated with economic policies or anticipated contingencies. The complete model consists of an interindustry model and macroeconomic model that integrates demand and supply conditions for consumption, investment, capital and labor. The macroeconomic model separates economic activity into four types of goods and services: the output of consumption and investment goods; and the inputs of capital and labor. The demand and supply of each commodity is calculated as well as market clearing prices and quantities. A household submodel determines the demand for consumption goods, supply of savings, and the supply of labor. A production function relates the output of consumption and investment goods to the inputs of capital and labor services, given the level of technical efficiency. The two other components of GNP, government expenditures and exports, are exogenous to the model. The interindustry model determines interindustry transactions for 36 sectors, the demand for primary inputs (labor, capital, and competitive imports), the allocation of GNP as final demand among the sectors, all total sector outputs. The technology of each producing sector is represented by a price possibility frontier that determines the supply price of output as a function of the prices of primary and intermediate inputs and the level of technical efficiency.

Item g: The version of DGEM tested in this study did not include a monetary policy model.[2] Via the TUTOR, a wide range of fiscal policy measures which are available to the U.S. government for use during or after a major event, such as military mobilization, may be modeled. Some of these policies involve purchases of goods and services; some policies control the allocation and use of available resources, in particular labor and capital; some policies control production activities, the level of operation of specific industries; and some policies affect fiscal conditions, such as government spending, taxation, and deficits.

[1] Berndt, E. R., op cit, pp 11-6.

[2] A newer version of DGEM is currently available which incorporates both monetary and fiscal policy.

These types of policies are included and can be specified by the analyst. For example, fiscal policy involves government revenues and expenditures, and their difference, the government deficit. Government revenues, primarily taxes, reduce the level of private disposable income and spending. Government purchases are themselves an element of spending and directly add to private spending in demand for goods and services. The government deficit affects the capital markets, since the deficit is financed by government borrowing. The larger the deficit, the more private capital is preempted (i.e., crowded out), reducing the availability of funds for private spending, and showing up particularly in its effect on private investment. Each of these policy measures is available to the government and each can be adjusted by the analyst in designing the analysis of the event.

Item h: DGEM models the U.S. economy as a sequence of annual equilibria that determine demand, supply, and the relative prices for all commodities. In each period the supply of capital is fixed initially by past investments and depreciation. Variations in demand for capital services by producing sectors and households affect the price, but not the quantity of capital services. However, present investment plans will alter the future level of the capital stock. Similarly, in each period the available labor time is fixed by past demographic developments, but variations in the demand for labor time by the producing sectors and by the households for leisure consumption affect the price of labor and the allocation of labor time between work and leisure. In addition, the supply of saving is simultaneously determined in the household model and must be in equilibrium with respect to investment demand. In each new period, an equilibrium is determined for all factor and product markets by integrating a macroeconomic model with an interindustry model (see the discussion under Item f).

Item i: At the present time, DGEM consists of 36 producing industries. More precisely, the DGEM analysis framework includes: (1) inputs to each industry from each of the 36 producing industries and from capital, labor and competitive imports; and (2) outputs from each industry to each of the 36 producing industries and to final demand -- personal consumption, investment, government purchases (specifically, federal defense, federal nondefense, and state and local government), and exports. Bridge tables, either within DGEM or between the TUTOR and DGEM, are of crucial importance for most military applications. The reasoning behind the previous statement is that bottlenecks are more likely to occur as the sectoral level of detail is increased. Conversely, the higher the level of aggregation, the less likely is the analyst to be able to identify a potential bottleneck. Based on the previous discussion, it should be clear that bottlenecks within DGEM's 36 sector framework can be identified, analyzed and to a certain extent alleviated. The question thus becomes one of sectoral detail. The discussion in Appendix D, where a multimodel approach to military mobilization is reviewed, expands upon this subject. It is also worth noting that the sectoral level of detail of DGEM differs significantly from two other military mobilization models, ROCS (115 sectors) and DEIMS (400 sectors), as well as the BEA benchmark input-output table (537 sectors). This lack of sectoral detail is probably the most serious deficiency of DGEM with regard to military mobilization applications.

Based on our review of DGEM, both the model's source code and documentation and the TUTOR, it is clear that the addition of two bridge tables would substantially enhance the ability of DGEM to provide a detailed analytical framework for a wide variety of military mobilization applications. The first is a "pre-processor" which incorporates a bridge into the TUTOR between the 55 defense procurement categories used in DEIMS and DGEM's 36 producing sectors. Alternatively, the "pre-processor" bridge table could be between DoC's defense procurement categories list and DGEM's 36 producing sectors. The discussion in Appendix D addresses some of the pros and cons of both DoD's and DoC's bridge tables between their respective defense procurement categories and the economy's producing sectors. The second is a "post-processor" which translates the DGEM output into a form which is consistent with DoC's 4-digit Standard Industrial Classification (SIC) level. If this were done, the output of DGEM would be consistent with the BEA benchmark input-output table. We note that the "pre-processor" bridge table discussed earlier may be incorporated in a relatively straight-forward manner. This is because much of the logic has already been incorporated into the TUTOR. Recall that government purchases are separated into three types of government activity: (1) federal defense; (2) federal nondefense; and (3) state and local government. In turn, each type of government activity involves purchases, spread over a number of supplying industries. For federal defense purchases, a rudimentary bridge table, which distributes defense purchases from the 55 DoD procurement categories to the 36 producing sectors, is included in the TUTOR. The analyst can therefore control defense spending in a variety of ways within this structure. Overall levels of defense spending can be altered, leaving the composition unchanged, or the composition and level can be changed. Specific defense procurement categories can be altered, year-by-year. Federal nondefense purchases and state and local government purchases are spread over the 36 producing sectors. Federal nondefense purchases can also be altered in total or industry-by-industry. State and local purchases can be altered in total, although the composition remains the same. The development of a "post-processor" bridge table is somewhat more complex, but, in principle, most of the data exists to go from the NIPA components to the 4-digit SIC level of detail.[1]

[1] The discussion in Appendix D outlines one way in which this activity might be accomplished.

REFERENCES

Alsmiller, J.R., et al. Adjoint Sensitivity Theory and Its Application to Leap Model 22C. Oak Ridge, TN: Oak Ridge National Laboratory, ORNL/TM-7789, 1981.

Chapman, R.E., R.G. Hendrickson and S.F. Weber. A Survey of Techniques for Evaluating Emergency Planning Models and Data Bases. Gaithersburg, MD: National Bureau of Standards, NBSIR 84-2963, 1984.

Comprehensive Emergency Management: A Review Leader's Guide. Washington, DC: National Governors' Association, 1981.

Computer Model Documentation Guide. Gaithersburg, MD: National Bureau of Standards, Special Publication 500-73, 1981.

Filliben, J.J. DATAPLOT - Introduction and Overview. Gaithersburg, MD: National Bureau of Standards, Special Publication 667, 1984.

Filliben, J.J. "Testing Basic Assumptions in the Measurement Process," in Validation of the Measurement Process. New York: American Chemical Society, ACS Symposium Series No. 63, pp. 30-113, 1977.

Gass, S.I. "Documenting a Computer-Based Model," Interfaces, Vol. 14, No. 3, 1984, pp. 84-93.

Gass, S.I. "Decision-Aiding Models, Validation, Assessment, and Related Issues for Policy Analysis," Operations Research, Vol. 31, No. 4, 1983, pp. 603-631.

Gass, S.I. (ed.). Utility and Use of Large-Scale Mathematical Models. Gaithersburg, MD: National Bureau of Standards, Special Publication 534, 1976.

Gass, S.I. and S. Parikh, "Credible Baseline Analysis for Multi-Model Public Policy Studies," in Energy Model and Studies, B. Lev, (ed.), North-Holland, 1983.

Gass, S.I. and S. Parikh, "On the Determinants of Credible Analysis," in Mathematical Modeling in Science and Technology, X.J.R. Avula (ed.), Pergamon Press, 1984.

Guidelines for Documentation of Computer Programs and Automated Data Systems. Gaithersburg, MD: National Bureau of Standards, FIPS PUB 38, 1976.

Harris, C.M. Issues in Sensitivity and Statistical Analysis of Large-Scale, Computer-Based Models. Gaithersburg, MD: National Bureau of Standards, NBS GCR 84-466, 1984.

Harris, C.M. Computer Generation of Latin Hypercube Sampling Plans. Gaithersburg, MD: National Bureau of Standards, NBS GCR 84-476, 1984.

Harris, C.M. "An Assessment of Climatological Uncertainties Using Monte-Carlo Analysis," in Selected Assessment Strategies Applied to Short-Term Energy Models. Gaithersburg, MD: National Bureau of Standards, NBSIR 83-2672, pp. 30-54, 1983.

Hendrickson, R.G. A Survey of Sensitivity Analysis Methodology. Gaithersburg, MD: National Bureau of Standards, NBSIR 84-2814, 1984.

Hudson, E.A. and Jorgenson, D.W. The Long Term Interindustry Transactions Model: A Simulation Model for Energy and Economic Analysis, Washington, DC: Federal Preparedness Agency, 1979.

Hudson, E.A. and Jorgenson, D.W. "U.S. Energy Policy and Economic Growth, 1975-2000, "The Bell Journal of Economics and Management Science, Vol. 5, No. 2, Autumn 1974, pp. 461-514.

Hudson, E.A. and Jorgenson, D.W. "Assessment and Selection of Models for Energy and Economic Analysis," in Validation and Assessment Issues of Energy Models, S.I. Gass (Ed.), Gaithersburg, MD: National Bureau of Standards, NBS Special Publication 569, 1980, pp. 431-444.

McKay, M.D., W.J. Conover, and R.J. Beckman, "A Comparison of Three Methods for Selecting Values of Input Variables in the Analysis of Output from a Computer Code," Technometrics, Vol. 21, No. 2, 1979, pp. 239-245.

Simulations of the 36 DGEM Over the Historical Period, Lexington, MA: Data Resources, Inc., 1980.

Test and Sensitivity Simulations of the 36 Sector Dynamic General Equilibrium Model, Lexington, MA: Data Resources, Inc., 1980.

The 36 Sector Model of Household Behavior, Lexington, MA: Data Resources, Inc., 1979.

The 36 Sector Model of Producer Behavior, Lexington, MA: Data Resources, Inc., 1979.

Tocher, K.D. The Art of Simulation. Princeton, NJ: D. Van Nostrand, 1963.

Weisbin, C.R., R.W. Peele, and A.S. Loebl. An Approach to Evaluating Energy-Economy Models. Oak Ridge, TN: Oak Ridge National Laboratory, ORNL-5742, 1981.

APPENDIX A: CRITICAL STAGES IN THE DEVELOPMENT OF LARGE-SCALE COMPUTER-BASED SYSTSEMS[1]

The purpose of this appendix is to describe those factors to consider when managing large-scale, computer-based model development activities. The five-phased approach for the factors presented in this appendix can greatly improve the management of these activities and make large-scale, computer-based models more responsive to user needs. The more responsive these models are to user needs the more effective and efficient they should be in providing information to the decision-making process.

The following factors are the product of an analysis of management weaknesses which are inherent in modeling development problems. These factors also suggest procedures which are intended to serve as a reference document for managing the development of large-scale, computer-based models.

Recommendations for the management of large-scale, computer-based model development efforts are divided into five separate phases: problem definition; preliminary design; detailed design; evaluation; and maintenance. In each phase we describe suggested specific duties and responsibilities of the user and the developer. Requirements for documentation should be met as necessary in each of the five phases.

The problem definition phase is primarily intended to describe those tasks that should be carried out by the user before agreeing to a model design. Additionally, the phase also describes design considerations and when appropriate, the contractual relationships which the user must determine before deciding whether a preliminary design effort should begin. During this phase, the user should be acquiring a clear definition of the problem. If the information being acquired during this phase indicates development should be stopped before the end of the phase, the user should be prepared to terminate development at this point. To determine whether to continue into the next phase, the user should consolidate and thoroughly review work completed during this phase. At this point the user should be confident that his needs will be met by the model without making changes to decisions that have been made. Once the decision is made to proceed to the preliminary design phase, a report should be prepared which provides specific guidelines to be followed in the remaining phases. These guidelines represent (contractual) responsibilities for the development of the model.

The preliminary design phase includes specification of the information content, general programming logic, and model algorithms necessary to develop a useful model. Preliminary design of the model should be conducted by the developer with information input and direction provided by the user. At completion of this phase, the user should consolidate and thoroughly review work completed on these factors. At this point the user should be confident that all of the specifications necessary to develop a useful model have been identified

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[1]Portions of this appendix are excerpted from: Gass, S. I. (editor), Utility and Use of Large-Scale Mathematical Models. Gaithersburg, MD: National Bureau of Standards, Special Publication 534, 1976.

and agreed to, and will not need to be changed during the following phases. The user must then determine the contract or work agreement process to be followed. The contract or work agreement should include specifications for the model and the control, documentation, and report requirements of the following two or three phases, as applicable (detailed design, evaluation, and maintenance).

In the detailed design phase the developer designs the model logic and prepares detailed programs. Briefings should be held periodically between the the developer and the user. One purpose of these briefings is to provide the user with the knowledge and confidence necessary to apply the model. During this phase, the user should continuously reevaluate the design being implemented and, if necessary, should recommend minor changes within the scope of the contract or work agreement. The user should always be available to the developer to answer questions and provide needed information. Before continuing into the next phase, the user should consolidate and thoroughly review the work completed in this phase. This review should provide the software manager with sufficient updated information to determine the adequacy and responsiveness of the development effort at this point. If the model has been adequately developed to meet the user's needs, procedures for evaluation of the model should be established, documented and carried out in the next phase.

The evaluation phase provides for the final check of the model as a whole. This operational testing supplements the evaluation of individual model programs conducted during earlier phases. The user has ultimate responsibility for evaluating the adequacy of the developed model. Actual evaluation of the model, however, may be done by the user, both user and developer, and/or an independent third party. Evaluation of the model is done according to the evaluation criteria and test plan established in the problem definition phase. Evaluation includes the determination of compliance with previously established agreements. At the completion of this phase, the user should prepare a report based on the evaluation work. This report should include the user's overall satisfaction or dissatisfaction with the modeling effort and the final model design. A decision should then be made as to whether or not the model is usable.

In the maintenance phase the Federal agency that sponsored model development establishes procedures for updating the model and for obtaining from the users their comments on the adequacy of the model and whatever changes they made to the model. The developer should be available for assisting the user after completion of model development in accordance with the agreement established during the preliminary design phase. Agency management should obtain from the user an abstract of the model application to provide information to others. Periodic reports should be prepared showing any changes made to the model and indicating the current status of the model. When the model can no longer meet user needs, its maintenance should be stopped and the status should show it is not usable.

In summary, the factors represent some suggested procedures for model development. They are intended to illustrate at least one method of enhancing the user's perspective of modeling and reducing the chance of failure during model development. They are presented in a form that: (1) distinguishes five separate phases of model development; (2) promotes a more thorough early investigation of the nature of the problem and of possible solution methods; and (3) provides a method of controlling the commitment to a modeling effort during the model's development period.

APPENDIX B: SPECIALIZED TECHNIQUES FOR PERFORMING A DATA AUDIT[1]

As discussed in Chapter 4, the statistical techniques used in a data audit fall into two major classes: (1) exploratory data analysis techniques; and (2) classical statistical techniques. Although the approach taken for each class of techniques differs significantly, both classes focus on the same key measures. These measures are: (1) central tendency: (2) distributional form; and (3) relational properties. In the text which follows, emphasis will first be placed on exploratory data analysis techniques. The discussion of classical statistical techniques follows immediately.

An important summary of the central tendency of a data set is a box and whisker plot. This graphical display highlights five important characteristics of the data set. The box, usually aligned vertically, encloses the interquantile range of the data, with the lower line identifying the 25th percentile and the upper line the 75th percentile. A line sectioning the box displays the location of the median within the interquantile range. The whiskers (line segments) at either end may extend to the extreme values or, for large data sets, to the 10th or 90th percentiles or 5th and 95th percentiles. Box plots are particularly useful for comparing the measures of central tendency for two or more data sets or different segments of the same data set.

Two techniques which are particularly useful for measuring the central tendency of a data set as well as providing a summary of distributional form are histograms and stem and leaf diagrams. Both techniques sort the data from smallest to largest and assign them to a group. Generally, the analyst must select the interval widths or the number of groups prior to the analysis. Once this has been done, a histogram becomes a graphical representation of a frequency distribution. Histograms typically use the heights of bars to exhibit the relative frequency of occurrences within each group of values within the data set. The main uses of a histogram in a data audit are: (1) to condense a set of data for easy visual comprehension of general characteristics such as typical values, dispersion, and shape; (2) to suggest probability models or transformations for subsequent analysis; and (3) to detect unexpected behavior or unusual values in the data.

An important variant of the histogram is the stem and leaf diagram. A stem and leaf diagram has the appearance of a histogram placed on its side. Each group defines a stem and each piece of information (item) on a stem is a leaf. The stem appears on the left side of a vertical line and the leaves appear on the right side of the vertical line. The leaves may be labeled so that the diagram preserves information distribution within groups. An additional feature of these diagrams is a summary column which represents the cumulative number of observations from each end of the data distribution (termed depths) up to the group containing the median. The major advantages of stem and leaf diagrams are that they show: (1) clearer separation into groups; (2) unsymmetric trailing off; (3) unexpectedly popular and/or unpopular values; (4) where the data are centered; and (5) how widely the data are spread.

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[1] Portions of the text which follows are abstracted from: Filliben, J. J. "Testing Basic Assumptions in the Measurement Process," in _Validation of the Measurement Process_, New York: American Chemical Society, ACS Symposium Series No. 63, pp. 30-113, 1977.

Although histograms and stem and leaf diagrams provide some insight into the underlying distribution of the data, probability plots permit specific hypotheses about the distributional properties of the data to be tested. A probability plot is a graphical tool for assessing the goodness of fit of some hypothesized distribution to an observed data set. A probability plot is (in general) simply a plot of the observed ordered (smallest to largest) observations, Y_i, on the vertical axis versus the corresponding typical ordered observations, M_i, on the horizontal axis based on whatever distribution is being hypothesized. Thus, for example, if one were forming a normal probability plot, the following n coordinate plot points would be formed: (Y_1, M_1) (Y_2, M_2)...(Y_n, M_n) where Y_1 is the observed smallest data point, and M_1 is the theoretical "expected" value of the smallest data point from a sample of size n normally distributed points.

Similarly, Y_2 would be the second smallest observed value and M_2 would be the "expected value" of the second smallest observation in a sample of size n from a normal distribution. Thus, in forming a normal probability plot, the vertical axis values depend only on the observed data, while the horizontal axis values are generated independently of the observed data and depend only on the theoretical distribution being tested or hypothesized (normality in this case) and also the value of the sample size n. A probability plot is thus in simplest terms a plot of the observed versus the theoretical or "expected."

The crux of the probability plot is that the i^{th} ordered observation in a sample of size n from some distribution is itself a random variable which has a distribution unto itself. This distribution of the i^{th} ordered observation can be theoretically derived and summarized, as can any other random variable. One can then pose the relevant question as to what single number best typifies the distribution associated with a given ordered observation in a sample of size n. In view of the resistance of the median to misbehavior in the data, the M_i on the horizontal axis of the probability plot is taken to be the median of the distribution of the i^{th} ordered observation in a sample of size n from whatever underlying distribution is being tested.

It is noted that the set of M_i as a whole will change from one hypothesized distribution to another -- and therein lies the distributional sensitivity of the probability plot technique. For example, if the hypothesized distribution is uniform, then a uniform probability plot would be formed and the M_i will be approximately equi-spaced to reflect the flat nature of the uniform probability density function. On the other hand, if the hypothesized distribution is normal, then the M_i will have a rather sparse spacing for the first few (M_1, M_2, M_3...) and last few (..., M_{n-2}, M_{n-1}, M_n) values but will become more densely spaced as one proceeds toward the middle of the set (..., $M_{n-1/2}$, $M_{n/2}$, $M_{n+1/2}$,...). Such behavior for the M_i is of course reflecting the bell-shape of the normal probability density function.

How does one use and interpret probability plots? In light of the above, it is seen that if in fact the observed data do have a distribution that the analyst has hypothesized, then (except for an unimportant location and scale factor which can be determined after the fact) the Y_i and M_i will be near-identical for all i, that is, over the entire set. Consequently, the plot of Y_i versus M_i will be near-linear. This linearity is the dominant feature to be checked for in any probability plot. A linear probability plot indicates that the hypothesized distribution, D_0, gives a good distributional fit to the observed data set. This combination of simplicity of use along with distributional sensitivity makes the probability plot an extremely powerful tool for data analysis.

Graphical analysis techniques are particularly helpful at analyzing relational properties. Techniques such as scatter diagrams, run sequence plots and lag-1 autocorrelation plots are important tools for the analyst. A usual first step in analyzing the relationship between two variables is to construct a scatter diagram, a collection of plotted points representing the pairs (x_i, y_i), $i=1,..,n$.

Scatter diagrams are also a useful precursor to regression analyses. The objective of regression analyses is to develop a mathematical relationship between a measured response or dependent variable, y, and two or more predictor or independent variables, $x_1, x_2,....x_p$. A usual initial step is to plot y versus each of the x variables individually and to plot each x versus each of the other x's. This results in a total of $p + p(p - 1)/2$ plots. Plots of y versus x_i, enable one to identify the x_i variables which appear to have large effects, to assess the form of a relationship between the y and x_i variables, and to determine whether any unusual data points are present. Plots of x_i vs. x_j, $i \neq j$, help to identify strong correlations that may exist among the predictor variables.

The run sequence plot is the next tool for analyzing relational properties. Although the collection of data points may or may not have been equispaced in time, the ordering of the data in time (i.e., the run sequence) is usually well-defined. In cases where the data acquisition rate is such that there is an equal time-spacing between collected data points, the run sequence has a natural analogue to a possibly relevant factor (time). In other cases, when the data acquisition rate is variable or random, no such analogue exists -- yet the run sequence "factor" is still frequently of interest. The run sequence plot (defined as a plot of Y_i versus i) is the simplest possible data plot and yet is almost invariably informative. The run sequence plot is the recommended first step in assessing whether such basic assumptions as fixed location, fixed variation and the implicit corollary assumptions hold-up, namely that the data set is outlier-free. With regard to economic data, the run sequence plot may help to identify seasonal and/or other trends.

The lag-1 autocorrelation plot is defined as a plot of Y_i versus Y_{i-1} over the entire data set; that is, the following n-1 points are plotted: (Y_2, Y_1), (Y_3, Y_2), (Y_4, Y_3),...(Y_n, Y_{n-1}). The lag-1 autocorrelation plot is sensitive to randomness assumptions governing the data. If the data are random, then adjacent observations will be uncorrelated and the plot of Y_i versus Y_{i-1} will appear as a data cloud with no apparent structure. However, if the data are not random and if adjacent observations do have some autocorrelation this structure will frequently manifest itself in the autocorrelation plot.

Part of the motivation of the previous discussion was to demonstrate how techniques based on exploratory data analysis complement classical statistical analysis techniques. In the discussion which follows, we shall introduce some of the most important classical tehniques with particular emphasis being placed on how these techniques can draw on information produced through an exploratory examination of the data.

As a first cut, it may be helpful to determine the minimum and maximum values of the variables within the data set. The range is then the difference between the maximum and minimum values. It is also helpful to determine the mode, or most popular value, as well as the median. The mean is the most common measure of central tendency. Often referred to as the average, it is merely the sum of the individual values for each case divided by the number of cases. The variance of the sample, s^2, is a measure of the dispersion of the data about the mean. This statistic is one way of measuring how closely the individual values of the variable cluster around the mean. Mathematically, it is the average squared deviation from the mean. Squaring the deviations from the mean takes into account all differences from the mean, including negative differences, and gives additional weight to extreme cases. The standard deviation is another measure of dispersion about the mean; it is the square root of the variance. The advantage of the standard deviation is that it has a more intuitive interpretation, being based on the same units as the original variable. If an infinite number of equal-sized samples were drawn from a given population, the mean of each sample would be an estimate of the true population mean, but not all of them would be identical. The pattern of these means would actually constitute a normal distribution and would have a standard deviation. The standard deviation of this distribution is the standard error. Thus, the standard error helps to determine the potential degree of discrepancy between the sample mean and the usually unknown population mean. Skewness is a statistic needed to determine the degree to which a distribution of cases approximates a normal curve, since it measures deviations from symmetry. The measure of skewness is sometimes called the third moment and will take on a value of zero when the distribution is completely symmetric. A positive value indicates that the cases are clustered more to the left of the mean with most of the extreme values to the right. A negative value indicates clustering to the right. Kurtosis is a measure of the relative peakedness or flatness of the curve defined by the distribution of cases. A normal distribution will have a kurtosis of zero. If the kurtosis is positive, then the distribution is more peaked (narrow) than would be true for a normal distribution, while a negative value means that it is flatter. Kurtosis is sometimes called the fourth moment.

Partial correlation provides the analyst with a single measure of association describing the relationship between two variables while adjusting for the effects of one or more additional variables. In essence, partial correlation enables the analyst to remove the effect of the control variable from the relationship between the independent and dependent variables without physically manipulating the raw data. In partial correlation the effect of the control variable(s) is assumed to be linear throughout its range, and it is this linear assumption that makes partial correlation possible.

Partial correlation can be used in a wide variety of ways to aid the researcher in understanding and clarifying relationships between three or more variables. When properly employed, partial correlation becomes an excellent technique for uncovering spurious relationships, locating intervening variables, and can even be used to help the researcher make certain types of causal inferences. Partial correlation can be a very helpful tool for enabling the researcher to locate spurious relationships. A spurious correlation is defined in a relationship between two variables, A and B for example, in which A's correlation with B is solely the result of the fact that A varies along with some other variable, C for example, which is indeed the true predictor of B. In this case, when the effects of C are controlled, held constant, etc., B no longer varies with A.

Another important feature of partial correlation lies in its ability to aid the analyst in a search for intervening linking variables. While there is no statistical difference between the computation of partials employed to locate spurious relationships and those used to determine intervening variables, the conceptual issues are different enough to merit separate treatment. The search for intervening variables is highly related to the issue of causality insofar as the researcher wishes to make statements of the sort: A leads to B which in turn leads to C. While partial correlation can be of great assistance in such problems, theoretical considerations become much more important in these types of situations.

Multiple regression is a general statistical technique through which one can analyze the relationship between a dependent variable and a set of independent or predictor variables. Multiple regression may be viewed either as a descriptive tool by which the linear dependence of one variable on others is summarized and decomposed, or as an inferential tool by which the relationships in the population are evaluated from the examination of sample data. Although these two aspects of the statistical technique are closely related, it is convenient to treat each separately, at least on a conceptual level. Since the method (as a descriptive tool or inferential tool) can be used for a variety of related purposes, we will illustrate only a few of its most common applications. The most important uses of the technique as a descriptive tool are: (1) to find the best linear prediction equation and evaluate its prediction accuracy; (2) to control for other confounding factors in order to evaluate the contribution of a specific variable or set of variables; and (3) to find structural relations and provide explanations for seemingly complex multivariate relationships.

For every use of regression as a descriptive tool, there is usually a corresponding question of statistical inference -- whether one can generalize the results of the sample observation to the universe. The problems of statistical inference can be conveniently grouped into two general categories: estimation and hypothesis testing. The purpose of estimation is to find the most likely population parameters from the examination of sample observations. The main focus here is in delineating a particular value or values for the population. The analyst may, on the other hand, focus on evaluating various hypotheses about the population. That is, instead of asking what value a population parameter is likely to have, one may simply test the null hypothesis that its value is zero against the alternative hypothesis that its value is greater or less than zero.

As mentioned in the previous subsection, any thorough statistical analysis should focus on an analysis of residuals. If a fitting procedure, such as multiple regression is used, then the residuals which remain are assumed to be random. The runs test is therefore of particular importance since it is specifically used to test for randomness. The underlying theory behind the runs test is that if the data are random and <u>if</u> the sample size is known (say n=50), the <u>number</u> of runs up of length 1, of length 2, <u>etc</u>., may be considered as random variables whose expected values and standard deviations can be calculated from theoretical considerations and these calculations will not depend on the (unknown) distribution of the data but only on its assumed randomness. Having computed such theoretical values, the final step in the test is to compute from the data the observed number of runs (up) of length 1, of length 2, etc., and then determine how many theoretical standard deviations that this observed statistic falls from the theoretically expected value. This is most easily done by formation of the standardized variable:

$$[N_i - E(N_i)]/SD(N_i)$$

where N_i is the observed number of runs (up) of length i, $E(N_i)$ is the theoretical expected number of runs up of length i and $SD(N_i)$ is the theoretical standard deviation of the number of runs of length i. For random data, one would expect values of say, ±1, ±2, ±3, i.e., the observed number of runs of length 1 should be only a few (at most) standard deviations away from the theoretical expected value for the number of runs of length 1. For nonrandom data, the deviations from the expected values will, of course, be much larger and this is the crux of the runs test.

A great deal of data in business, economics and engineering occur in the form of time series, where observations are dependent and where the nature of the dependence is of interest in itself. The body of techniques available for the analysis of such series of dependent observations is called time series analysis. Box-Jenkins techniques are concerned with the building of models for discrete time series. In particular, time series are often best represented by nonstationary models in which trends and other pseudo-systematic characteristics which can change with time are treated as stochastic rather than deterministic phenomena. Furthermore, economic time series often possess marked seasonal or periodic components themselves, capable of change and needing (possibly nonstationary) seasonal models for their description. Much of the motivation behind the Box-Jenkins approach can be seen through reference to Wold's decomposition theorem. This theorem demonstrates that any covariance stationary process can be decomposed into two parts, η_t and ξ_t, where η_t is a purely deterministic part and ξ_t is the purely stochastic part. A corollary of Wold's theorem is that ξ_t can be expressed as a one-sided moving average process of infinite order

$$\xi_t = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2} - \cdots$$

or

$$\xi_t = - \sum_{j=o}^{\infty} - \theta_j a_{t-j}$$

where $\{a_t\}$ is a sequence of uncorrelated random variables and

$$E(a_t) = 0 \text{ for all } t$$

$$E(a_t)^2 = \sigma_a^2 \text{ for all } t$$

$$E(a_t a_s) = 0 \text{ if } t \neq s$$

The Box-Jenkins approach seeks to induce stationarity into the stochastic process $\{Y_t\}$ by designing filters such that

$$Z_t = \Delta_s^{d_2} \Delta^{d_1} ((Y_t+u)^{\lambda} -1)/\lambda$$

is a covariance stationary process where

$$\Delta = Y_t - Y_{t-1}$$

$$\Delta_s = Y_t - Y_{t-s}$$

$$((Y_t+u)^{\lambda} -1)/\lambda = \text{the Box-Cox power transformation.}$$

The mechanics of fitting such a model (i.e., obtaining estimates for d_1, d_2 and λ) involve an analysis of the behavior of the sample autocorrelation function and the sample partial autocorrelation function. With respect to Wold's decomposition theorem, the Box-Jenkins approach is based on two assumptions.

The first assumption is that the differencing operators, $\Delta_s^{d_2} \Delta^{d_1}$, and the power transformation force η_t to zero. The second assumption is that

$$\varepsilon_t = \phi_1 \varepsilon_{t-1} + \dots + \phi_p \varepsilon_{t-p} + a_t - \theta_1 a_{t-1} - \dots - \theta_q a_{t-q}$$

or

$$\phi(B)\varepsilon_t = \theta(B) a_t$$

where $\phi(B) = 1 - \phi_1 B - \dots - \phi_q B^P$

$\theta(B) = 1 - \theta_1 B - \dots - \theta_q B^q$

B = the backshift operator

Both assumptions permit the infinite number of parameters in the original model to be reduced to p+q+1 parameters, p autoregressive parameters, q moving average parameters, and the variance of a_t, σ_a. The previous statement shows that the types of models produced by Box-Jenkins techniques have a desirable property: they are parsimonious. Box-Jenkins models are parsimonious because they employ the smallest possible number of parameters for adequate representation.

APPENDIX C: THE EVALUATION OF MULTI-MODEL SYSTEMS[1]

In the previous sections of the report, the focus has been on describing evaluation considerations as they apply to a single, self-contained model. However, due to limitations on time and funds, many problems encountered by FEMA can only be studied in an expedient manner by combining existing models into a multi-model system in which the separate models receive data from and transmit data to one another. For such systems, the analytic aspects of evaluation, sensitivity analysis, data audits, and so on, are confounded and more complex than for a single model. The situation is further complicated as the individual models that are combined usually have evaluative and validation problems of their own, and the applicability of the individual model is stretched to meet the requirements of the multi-model area. In such situations, validation testing of the total multi-model system is not possible; such testing is usually ignored. The model analysts must, however, provide some evidence that the multi-model system is credible.

The main criterion of credibility is the notion of consistency. In any multi-model study, there is a requirement to establish a set of initial conditions -- baseline assumptions -- about which the analysis takes place. This requirement exists as the problem setting must be delineated; the models cannot be operated without fixing the many input parameters and initial variable settings that define the problem area. A complete statement of the baseline assumptions is essential in a multi-model analysis. It is termed the baseline scenario. Such a statement represents the major control mechanism by which the models and analysts are coordinated and consistency maintained throughout the analysis. That is, a proper baseline scenario ensures that the models (and analysts) are addressing the same problem, are using the same assumptions, and are starting with the same initial data.

A scenario, in general, represents a description of the problem area being analyzed; it is based on the model builders' and users' perception of the problem and the requirements of the models. Further, a scenario describes the factual and/or postulated settings of the situation, including, in model-based terms, descriptions of the future in which the analysis takes place. Any model-based analysis, especially a multi-model analysis, depends upon the construction, definition, interpretation and acceptance of the baseline and other scenarios by which the multi-model system is coordinated and comparative analyses takes place.

Although a scenario represents a statement about the future, it cannot be interpreted as a prediction, but only as a plausible future whose implications are to be analyzed by the modeling exercise. Scenario-based analyses are conducted by varying assumptions and/or data to determine how sensitive the results are to uncertain estimates of the future, for example, measuring the impact of uncertain estimates of inflation on GNP. Such variations usually are conducted about a reference or baseline scenario. The baseline scenario may be considered to be a description of the status quo and its most plausible projection into the future. The baseline scenario thus provides the reference

[1] Portions of this appendix are excerpted from: S. I. Gass, and S. Parikh, "Credible Baseline Analysis for Multi-Model Public Policy Studies," in Energy Models and Studies B. Lev (ed.), North-Holland, 1983.

conditions that are input to the multi-model exercise. It enables the analysts to produce a scenario impact analysis that is the result of the analysts translating the baseline assumptions into corresponding model inputs, the running of the models, and output analysis, including judgmental adjustments of model results. Taken together, the baseline scenario and the resulting impact analysis form the reference baseline analysis.

Some uncertainty usually surrounds many of the assumptions and data specifications of a baseline scenario. There is a need to measure the impact of this uncertainty by performing standard sensitivity studies on key assumptions and/or data of the baseline scenario. This can be an expensive and time-consuming activity and, thus, it is often limited to just a few alterations of the baseline scenario. The results of analyzing these alternate baseline scenarios represent, in a sense, the range of possible outcomes that can occur for the assumed baseline future. For example, high and low GNP estimates may be run and compared to the baseline (average) GNP, while keeping all other input elements constant. In many studies, the above type of analysis is the extent to which a multi-model system is employed.

By varying the assumptions and conditions of the baseline scenario, that is the views of the plausible future, policy impacts can be analyzed over a range of possible future outcomes and compared with the reference baseline analysis. Then, depending on their assessment of the most likely course of events, the analysts and study sponsors can account for the uncertainty in the exercise results. The impacts will often change with the scenario assumptions, but a consistent and controlled means of comparing policy implications of different futures is provided by a systematic use of the baseline and alternate baseline scenarios. A comparative analysis, based on the results of a number of plausible scenarios, puts the decision maker in a better position to decide which policies to implement.

In the above type of study, in which a baseline scenario is varied to reflect uncertainty, the set of choices (policy options) available to the multi-model system's decision process is not changed. Results change only because a different choice is made under the alternate baseline scenarios. Another and probably more important form of analysis occurs when policy options are proposed that modify the baseline policy specifications. The analysis then must be made using a set of choices that are different from the one available in the baseline analysis. Alternate policy scenarios are then used to produce policy analyses that can be compared to the baseline analysis to measure the impact of allowing new policy options. For example, a FEMA baseline scenario may stipulate that all steel production is to be given to the defense tier, with the level of steel production being an uncertain parameter about which sensitivity studies are made. But an alternate policy scenario may call for only 50% of the steel output going to the defense tier. Another example could have the baseline scenario requiring mobilization to be paid for by taxation, while an alternate policy scenario states that mobilization would be financed by deficit spending. The alternate policy scenarios are subject to the same unceratinties as the baseline scenario. To conduct a more complete policy study, the alternate policy should be varied and processed in the same manner as the alternate baseline scenarios. However, as the running of say, high, average, and low GNP variations for each scenario is costly and time consuming, a study is usually limited to just the processing and comparing of the average baseline and policy scenarios. We note that any differences in the two analyses are due to the model's decision logic that must select from the different policy options allowed by the scenarios.

Credibility of a multi-model system can be further enhanced if the reasons why the particular set of models was selected are discussed. For example, a model that has been used in the past with favorable results and does not need to be changed contributes positively to the notion of credibility; while a newly built model or one that must undergo extensive reprogramming will not inspire much credibility. No matter what the reasons are, they need to be made explicit. Further credibility enhancing elements include the active involvement of the user in specifying the scenarios and interpreting the results, and the use of experts in selecting the models and in reviewing the results.

APPENDIX D: THE POTENTIAL ROLE OF DGEM IN AN INTEGRATED SYSTEM FOR MILITARY MOBILIZATION[1]

There are several agencies within the Federal government responsible for estimating resource requirements in the event of a military emergency. Should an actual military emergency occur, these same agencies would also be responsible for allocating available resources among competing ends. The most obvious is the Department of Defense (DoD) which would be responsible for estimating the structure of the military forces to fulfill the requirements of winning or preventing a war. This would include estimates of dollar outlays to fulfill the force structure. The Department of Commerce (DoC) has the responsibility to evaluate the industrial base of the country and estimate the output of goods and services necessary to fulfill not only the requirements of the military, but also the requirements of the civilian economy. This task also includes estimates of production required for industrial investment in structures and equipment, net exports, state and local government expenditures, Federal government non-defense expenditures and personal consumption. In the production of output for investment and trade, it is very likely that the required output will compete with production for national defense. Closely tied to the Commerce Department estimates of output by industry are estimates of the labor force (employment and occupations). This task is performed by the Department of Labor (DoL).

Within the triangle of Federal agencies of DoD, DoC, and DoL is what might be considered the core necessary to evaluate the industrial production and employment effects of a military emergency. Within each of these agencies is the ability to estimate total production and employment needs for an emergency. However, the responsibility and the corresponding capabilities within each separate agency to analyze its resources argues for cooperation in mobilization analysis. As a result, these three agencies signed a Memorandum of Understanding in 1983 for cooperation in mobilization planning.

In addition to the resources monitored by DoD, DoC, and DoL, there are other Federal agencies responsible for monitoring and allocating resources in the event of a crisis. These include: (1) energy requirements monitored by the Department of Energy (DoE); (2) strategic and critical materials monitored by the Department of the Interior (DoI); (3) transportation requirements monitored by the Department of Transportation (DoT); and (4) food and agricultural requirements monitored by the Department of Agriculture (DoA).

This appendix outlines how these executive agencies can work together, and have worked in the past, to estimate the resources necessary to meet the requirements of a military emergency.

Central to the discussion in this appendix is the role of macroeconomic models in interagency mobilization analyses. Special emphasis is placed on how DGEM can complement proprietary models in such an analytical framework.

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[1]This appendix was prepared by David K. Henry and Albert Walderhaug of the Office of Business Analysis, Office of the Under Secretary for Economic Affairs, U. S. Department of Commerce. Several contributions by Robert E. Chapman, Center for Computing and Applied Mathematics, National Institute of Standards and Technology are also included.

This appendix does not attempt to concord all of the technical parameters of each agency's models and data. To concord each of these major models is a considerable task and would, and probably should as in past efforts, be accomplished while performing an interagency mobilization analysis. At that time, details such as the industry sectoring classification, constant dollar series, industry to commodity conversion, price valuation, and national accounting conventions should be accommodated and made consistent among the models and supporting data used by the Federal agencies participating in the analyses. The constant updating and change in the technical parameters of the models that can be used in interagency analysis is another reason for not attempting to concord the technical parameters in this appendix.

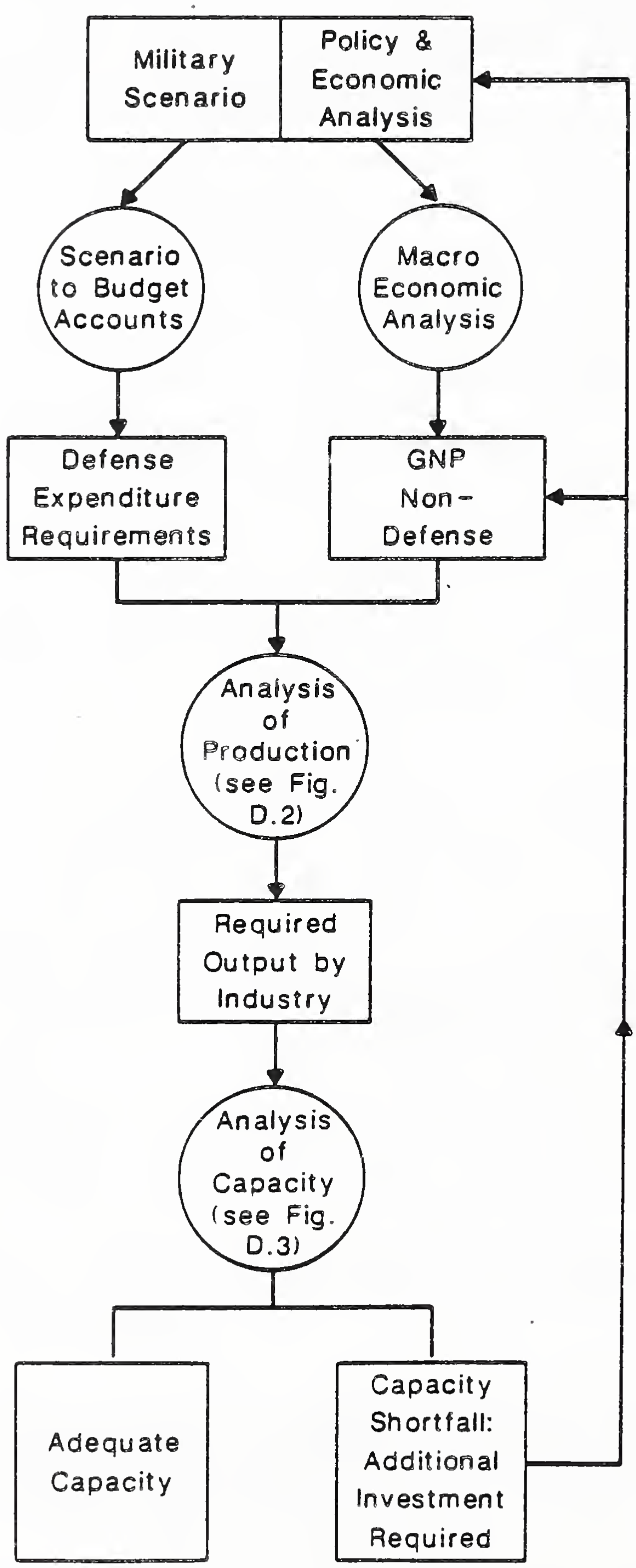
The most recent experience of coordinating a multi-Federal agency effort analyzing resources to meet the requirements of a military emergency was an exercise in 1984-85 that was coordinated by the Federal Emergency Management Agency (FEMA) and was called the Federal Resource Assessment System (FRAS). FRAS was set up under the Military Mobilization Working Group of the Emergency Mobilization Preparedness Board (EMPB). The Department of Commerce, Office of Business Analysis (OBA) was responsible for the technical coordination of all the participating Agencies. The effort resulted in a report to EMPB in 1985 which described the interagency effort and provided preliminary estimates of the resources. The EMPB dissolved shortly thereafter. Since then, a Senior Interagency Group (SIG) for National Security Emergency Planning has been established under the National Security Council. The Mobilization Planning Group under the SIG has been an attempt to continue an interagency governmental responsibility in mobilization planning.

Also in 1984-85, the National Security Council led an effort to evaluate the quantities of strategic and critical materials that should be maintained in the U. S. government's stockpiles in the event of a military emergency. The stockpile study used a similar approach to the FRAS analysis, since industrial output requirements during a military emergency needed to be estimated before the estimate of critical materials could be made. The stockpile review was also an interagency effort and a good portion of its military emergency assumptions were incorporated into the FRAS analysis.

In addition to the FRAS and the Stockpile interagency efforts to analyze the requirements of a military emergency, there was an interagency effort to evaluate the effects of imports on the machine tool industry for a Section 232 investigation under the 1962 Trade Expansion Act for Import Vulnerability. The results of the study led to the decision to apply Voluntary Restraint Agreements on the imports of machine tools into the United States.

Each of these studies required an evaluation of the resources of the entire economy. Military and civilian resource requirements estimates were made for products common within each industry and decisions were made about the industry's ability to meet these requirements. In each case, industrial output was estimated to fulfill the production of goods and services that were generated in an economy described by a level and composition of Gross National Product (GNP). The economy as described by its GNP was used as the first step in the analysis.

Figure D.1 Scenario Development and Analysis



The Economy Under A Mobilization

Implicit in any military mobilization preparedness study is a well-defined set of models, databases, and analysis strategy. Figure D.1 illustrates the process used to describe the domestic economy during an emergency.

The first stage of any such study is the specification of a scenario. A scenario is defined as an account or a synopsis of a projected course of actions or events. The military scenario describes a course of actions or events which includes an enemy threat, a basic strategy to meet the threat, the size and deployment of U.S. forces that fulfills the military strategy and the form and intensity of the combat expected. In turn, the size and deployment of U.S. forces requires a defense budget that accommodates or allows their support.

In addition to, or as a result of, the military scenario, there is an economic scenario which describes how the domestic economy reponds to the military emergency. In developing the economic scenario, policy decisions affect the way the economy reacts to meet the threat. Economic assumptions reflect, for example, the monetary and fiscal policies chosen to finance the war, the world energy supply and corresponding prices, and projections for the expected rate of growth of the economy and the Federal budget. Once the economy has been described, in quantitative terms, it is possible to estimate the production of goods and services to meet the requirements of the economy.

The need for macroeconomic (economy wide) analysis requires that models of the economy be used to determine the economy's size and composition. There are a number of proprietary models such as those marketed by Wharton, Chase and DRI available to be used by government agencies. In addition, there are some models developed within the government for special purpose analyses which incorporate economy wide analysis as a front-end to their special analyses: the Defense Economic Impact Modeling System (DEIMS), used by DoD to assess the market share of output for defense; the Economic Growth System (EGS) of the Bureau of Labor Statistics (BLS), used to analyze future needs for labor and skills as the economy grows and changes; as well as DGEM.

The proprietary models are, in general, peacetime models based on peacetime trends and relationships. Their suitability for mobilization analysis depends on the extent to which the structural relationships in the model can accommodate policy relevant variables dictated by the mobilization scenario and the economic objectives which are subject to the set of policy options. The options relate to how the economy will be managed to achieve the mobilization objectives and will involve: (1) tax policy and how it relates to persons and business; (2) fiscal policy as it determines how the emergency is financed; (3) monetary policy affecting the growth of money supply and its impact on interest rates; and (4) government actions affecting labor force participation rates and producitivity improvement incentives.

Since econometric models are based on historical relationships and trends, it is important that they incorporate and reflect up-to-date information to the maximum extent possible. The suitability of models from this aspect needs to be assessed. Furthermore, the release by the Bureau of Economic Analysis of the Department of Commerce of the 1977 input-output tables and rebenchmarking of the National Accounts to 1982 prices, which form the basis of the macroeconomic models and derivative models, may cause some problems of price compatibility and industry classification and structural relationships.

Recently, several Federal agencies have expressed interest in using DGEM to complement their modeling efforts. For example, DGEM may be used to forecast the values of key macroeconomic variables (e.g., GNP, Personal Consumption Expenditures, Investment, as well as other components of the National Income and Product Accounts (NIPA)) which may be needed as inputs for a particular model. Clearly, experiences gained by these Federal agencies would be beneficial in performing similar analyses with DGEM for a war-time economy.[1]

DGEM may be useful in this role for four other reasons. First and foremost, DGEM was designed to deal with the demand surges and resource constraints which are expected during the transition from a peace-time to a war-time economy. Specifically, DGEM explicitly addresses factors which affect both demand and supply on an annual basis up through the year 2000. Second, the TUTOR provides the user with a set of step-by-step instructions for incorporating information on Defense and other government expenditures as well as economic and technical considerations which specify how the economy mobilizes. Third, from a review of the documentation, it became clear that much care went into the design, development and testing of the model. Furthermore, the model's documentation is quite complete and should be sufficient to: (1) set it up on the host system; (2) execute a "base-case" simulation; (3) interpret the results of the "base-case" simulation; and (4) create, run, and interpret user-specified simulations. Finally, the DGEM source code has been made available to a number of users, enabling them to explore the major linkages within the model as well as trace the flow of calculations for particular (e.g., mobilization oriented) variables of interest.

These "strengths" must be weighed against the lack of sector-specific detail in DGEM. At the present time, DGEM consists of 36 producing industries. More precisely, the DGEM analysis framework includes: (1) inputs to each industry from each of the 36 producing industries and from capital, labor and competitive imports; and (2) outputs from each industry to each of the 36 producing industries and to final demand -- personal consumption, investment, government purchases (specifically, Federal defense, Federal nondefense, and state and local government), and exports. Bridge tables, either within DGEM or between the TUTOR and DGEM, are of crucial importance for most military applications. The reasoning behind the previous statement is that bottlenecks are more likely to occur as the sectoral level of detail is increased. Conversely, the higher the level of aggregation, the less likely is the analyst to be able to identify a potential bottleneck. Based on the previous discussion, it should be clear that bottlenecks within DGEM's 36 sector framework can be identified, analyzed and to a certain extent alleviated. The question thus becomes one of sectoral detail. It is also worth noting that the sectoral level of detail of DGEM differs significantly from DEIMS (400 sectors) and the BEA benchmark input-output table (537 sectors). This lack of sectoral detail is probably the most serious deficiency of DGEM with regard to military mobilization applications.

Based on our review of DGEM, both the model's source code and documentation and the TUTOR, it is clear that the addition of two bridge tables would substantially enhance the ability of DGEM to provide a detailed analytical

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[1] For a more detailed discussion of DGEM, the TUTOR, the DGEM analysis strategy, and other related topics, the interested reader is referred to Chapters 6 through 9.

framework for a wide variety of military mobilization applications. The first is a "pre-processor" which incorporates a bridge into the TUTOR between the 55 defense procurement categories used in DEIMS and DGEM's 36 producing sectors. Alternatively, the "pre-processor" bridge table could be between DoC's defense procurement categories list and DGEM's 36 producing sectors. In the text which follows some of the pros and cons of both DoD's and DoC's bridge tables between their respective defense procurement categories and the economy's producing sectors are discussed. The second is a "post-processor" which translates the DGEM output into a form which is consistent with DoC's 4-digit Standard Industrial Classification (SIC) level. If this were done, the output of DGEM would be consistent with the BEA benchmark input-output table. We note that the "pre-processor" bridge table discussed earlier may be incorporated in a relatively straight-forward manner. This is because much of the logic has already been incorporated into the TUTOR. Recall that government purchases are separated into three types of government activity: (1) Federal defense; (2) Federal nondefense; and (3) state and local government. In turn, each type of government activity involves purchases, spread over a number of supplying industries. For Federal defense purchases, a rudimentary bridge table, which distributes defense purchases from the 55 DoD procurement categories to the 36 producing sectors, is included in the TUTOR. The analyst can therefore control defense spending in a variety of ways within this structure. Overall levels of defense spending can be altered, leaving the composition unchanged, or the composition and level can be changed. Specific defense procurement categories can be altered, year by year. Federal nondefense purchases and state and local government purchases are spread over the 36 producing sectors. Federal nondefense purchases can also be altered in total or industry by industry. State and local purchases can be altered in total, although the composition remains the same. The development of a "post-processor" bridge table is somewhat more complex, but, in principle, most of the data exists to go from the NIPA components to the 4-digit SIC level of detail. If these steps were taken, an analysis framework similar to that outlined in Figures D.1 through D.3 and described in the text which follows would result.[1]

To summarize, the key outputs required from the macroeconomic model are the "snapshots" of the U.S. economy for the years in which the economy is distorted by a mobilization or a military emergency. The description of the economy needed in order to evaluate industrial requirements and supply conditions are the levels of real GNP and its composition.

Estimating Industrial Production and Supply

Figures D.2 and D.3 illustrate the process generally followed in analyzing the industrial impacts of major government programs, or responses to emergency situations. Within the parameters of GNP and its components, the output of goods and services implied by the scenario are estimated as well as the capability of the existing economy to fulfill the requirements.

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[1]It is important to point out that we view such an analysis framework based on DGEM as complementary to those based on collections of models and databases. It is neither reasonable nor desirable to have a single model, such as DGEM, supplant a loosely-coupled collection of models from several Federal agencies, but rather to use such a model to encourage consistency and an avenue for feedback within the overall analytical framework.

Figure D.2 Analysis of Production Requirements

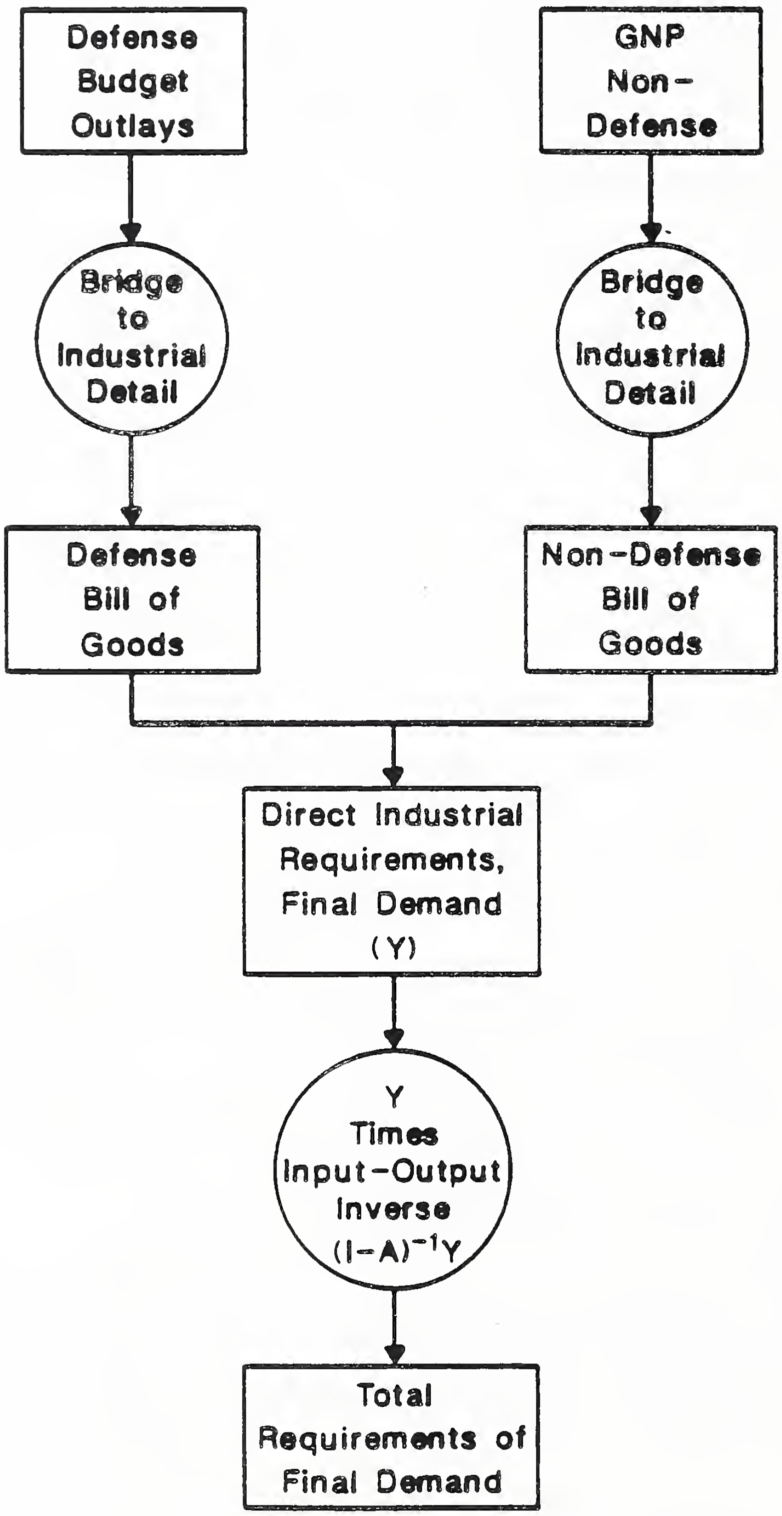
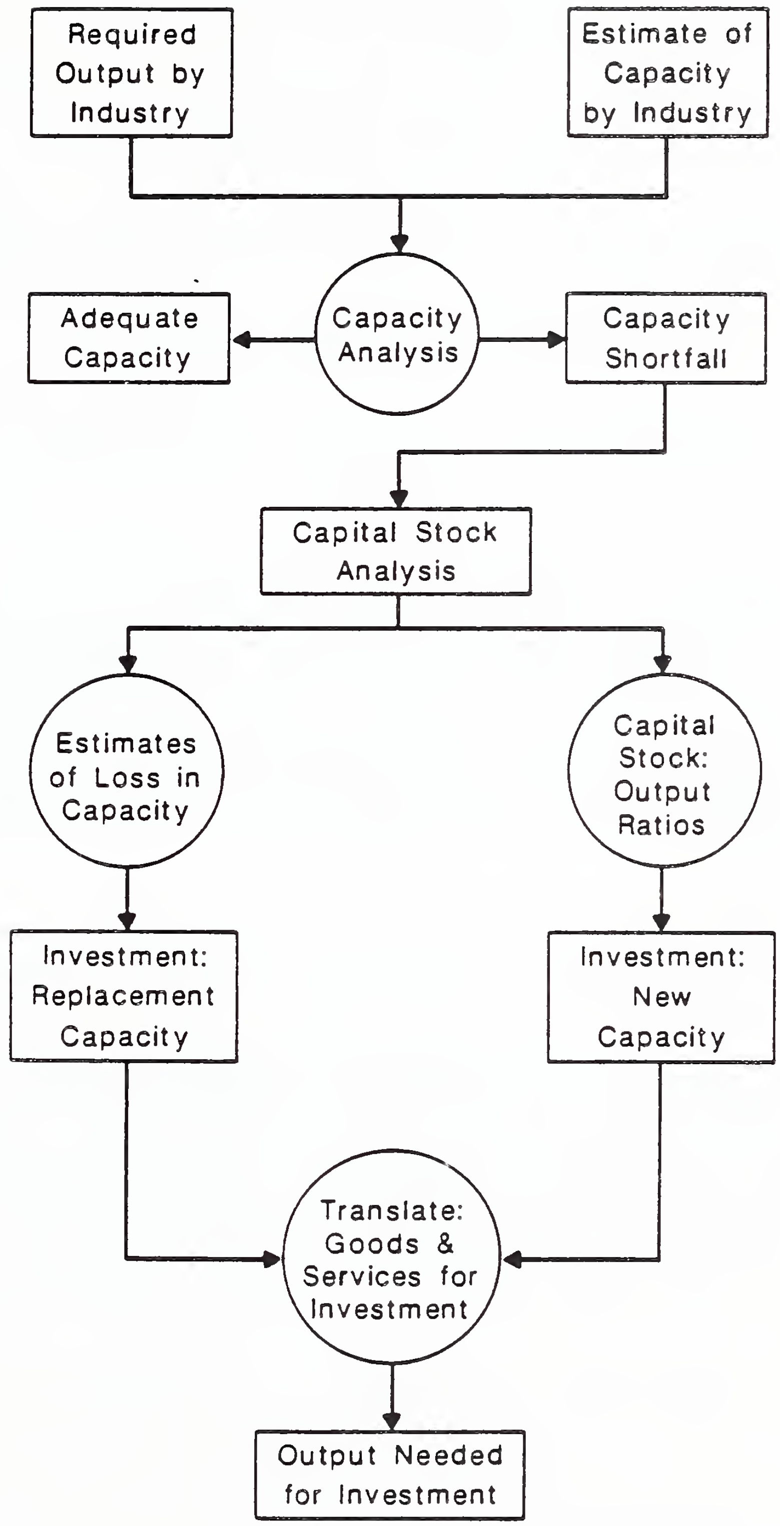


Figure D.3 Analysis of Capacity



OBA has developed bridge tables to be used in translating the final demand components of GNP into their industrial composition. These estimates show the direct impact of the final demand for goods and services on the producing industries of the economy. However, before the bridge tables can be used, a set of "control" totals must be established that correspond to the detail of the bridge tables. A macroeconometric model is used to establish the levels for most of the totals (composition of GNP).[1] However, as appropriate, in all of these mobilization exercises the level and composition of national defense spending deserves special attention.

Military Requirements

One of the most sensitive issues to be addressed by mobilization planners is the size and the composition of the military budget to meet the threat. Although the total national defense budget is a key exogenous variable in the macroeconomic analysis of the economy, the composition of national defense is necessary to allocate industrial final demand to the defense expenditures. For the FRAS, Stockpile Review and the Section 232 Machine Tool studies, the detail of the military budget estimates by budget category have been supplied by the Defense Department.

An alternative way to translate a military scenario into defense outlays by budget category has been through a model developed by The Analytical Sciences Corporation (TASC) for FEMA called TASCMAIN, or Technique for Assessing the Capability to Mobilize American Industry. Although TASCMAIN was designed to evaluate industrial supply and demand during a mobilization, its uniqueness for an interagency exercise is its ability to translate a military scenario into a force structure which is, in turn, translated into DoD budget accounts in dollars. These budget accounts are necessary for DoC to calculate military demand on industry.

Industrial Final Demands for Military Requirements

The emphasis of the work conducted in OBA to translate the GNP components of final demand into their industrial composition has been on Federal government expenditures for national defense. OBA has developed 34 bridge tables which translate DoD budget expenditures into their industrial composition. These bridge tables are keyed to defense budget categories: military personnel; operations and maintenance; procurement; research, development, testing and evaluation; military construction; family housing and non-DoD defense programs.

An alternative to the OBA translation of the defense budget to industrial final demands is by the use of the defense budget translators maintained by the Department of Defense's Program, Analysis and Evaluation Division. The translators are a part of the Defense Economic Impact Modeling System (DEIMS) and in a great many respects are similar to the translators or bridge tables maintained by the Department of Commerce.

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[1]OBA is currently exploring a number of ways in which DGEM may be used to generate the control totals required in defense-related studies.

The Civilian Economy

Estimates of components of GNP resulting from the macroeconomic analysis, in addition to Federal government expenditures for national defense, include expenditures for personal consumption, gross private capital formation, Federal expenditures for non-defense, state and local government expenditures, exports and imports. During peacetime, the percentage of GNP accounted for by national defense has ranged from 5 to 6 percent in recent years. For each of the civilian components of GNP, bridge tables were developed that describe their composition of industrial final demand. The expenditure-to-commodity relationships developed in the bridge tables reflect historical relationships. Therefore, the greater the GNP expenditure detail available from the macroeconomic model, the more flexibility there can be in using bridge tables to specify a "bill-of-goods" to describe the industrial composition of non-defense GNP or final demand.

Sub-Tier Production

Final demand does not reflect the intermediate goods and services which are consumed in making end products that are purchased for national defense or the rest of the economy. A further step is necessary to estimate the output of industries that is required to supply those indirect products, as well as the products entering final demand directly. This is accomplished using input-output techniques in which the bills-of-goods (aircraft, missiles, tanks, ships, etc.) are applied to an input-output inverse matrix which generates the prime contractor and sub-tier contractor requirements for output by industry to support the specified level and detail of GNP. The levels of total output, direct and indirect, by industry resulting from these operations form the basis for subsequent evaluations of the adequacy of resources to meet the requirements.

The input-output models of the U.S. industrial economy available for use in estimating the indirect output by industry to fulfill the final demand for goods and services required by the emergency are derived mainly from the 537-sector interindustry tables produced by DoC's Bureau of Economic Analysis (BEA). These derivative tables are condensed and in some cases updated versions of the BEA tables with industry classifications designed for specific purposes. The latest version of the BEA input-output tables are for 1977. The next revision of the benchmark table will be for 1982, although revisions for 1981 and 1982 of the more aggregated 80-industry order table have been produced. Other interindustry input-output tables, derived from the BEA benchmark table, include: the DRI interindustry model (432 sectors), the BLS Economic Growth System (156 sectors), the FEMA model called the Revised Growth for Industrial Potential, REGRIP, (115 sectors), and DoE's Energy Disaggregated Input-Output Model (130 sectors).

Industrial Capacity

Estimates of industrial capacity by which to assess the feasibility of producing the output as required during the emergency has and continues to be the weakest link in industrial analysis. The Bureau of the Census report entitled Survey of Plant Capacity lists capacity utilization rates for most manufacturing industries at the 4-digit Standard Industrial Classification (SIC) level. There are some considerable problems in utilizing the Census data for mobilization planning. The utilization rates are for fourth quarter activity only and are not average annual activity. If there was only one shift operating during the fourth quarter, estimated capacity is based on that one shift. During a military emergency, double and triple shifts could occur and the industry's capacity would increase accordingly. This increase would be offset somewhat by the faster rate of capital stock depletion.

FEMA recognized the problems in using industrial capacity data for mobilization planning. Consequently, they contracted ORI, Inc. to provide estimates of emergency capacity for manufacturing industries. The estimates for emergency capacity for mining, manufacturing, and utility industries include labor and capital shift factors and lead times for "greenfield" investments. The emergency capacity data developed by ORI, Inc. can be used in conjunction with the normal sources of capacity data from the Census and the Federal Reserve Board.

In the past, DoC conducted Industry Evaluation Board (IEB) studies to determine the capacities of defense-related industries. These capacity studies were done at a very high level of detail. The IEB capacity studies used considerable investigative resources and took a long time to complete. Survey forms and mailing lists were prepared and surveys mailed. Follow-ups were made to non-responders and the responses were reviewed and analyzed.

More recently, OBA, at the request of the National Security Council and the Office of Management and Budget, developed a methodology to assess the investment requirements of certain manufacturing industries to meet the industrial outputs projected for military mobilization.

The methodology to estimate new and replacement investment of the industries evaluated depend on OBA's data base on capital stocks of manufacturing industries. The OBA capital stock data base consists of measures of investment, capital stocks and related statistics for manufacturing industries. Twenty-one measures of capital stocks for structures and equipment are available.

In OBA's method for estimating new and replacement investment, ratios of capital stocks per unit of output are developed for each of the industries. Based on the requirements estimates, a determination can be made from these ratios as to the level of capital stocks necessary to support the industrial output requirements during the emergency. Comparing existing capital stocks to the emergency capital stocks requirements, and factoring the physical depreciation (discards and wear and tear) of the existing capital stocks into the emergency period, the amount of new investment can be calculated.

If the industrial output projection for defense related industry exceeds existing capacity, a decision must be made to provide or not provide for the new investment. If not provided for, the industry that needed the investment would have to be identified as a bottleneck industry — an industry unable to supply the estimated military and civilian requirements and an alternative policy decision on allocation of available supply would have to be made.

The investment in the industries needed to meet the emergency production levels is then distributed to the types of equipment and structures that are necessary to provide the facilities. For example, machine tools and testing and measuring equipment are important in the production of weapon systems. OBA maintains a capital flow matrix that identifies the types of equipment and structures in an industry's investment pattern.

These calculations of investment requirements really redefine the previous estimates of Gross Private Fixed Investment which have been estimated in a less refined fashion. In other words, the GNP is redefined and industrial requirements of all industries are restructured and additional output will be required from an undefined set of industries to meet this investment. Thus, a second or even third review of industrial capacity may be necessary.

Recently, FEMA developed a model to identify capacity shortfalls for industrial mobilization and the options to resolve them. The model will be used by the Army Material Command to analyze industrial preparedness. The model was named ROCS (Resolution of Capacity Shortfalls). The primary advantages of ROCS are: (1) that it can be implemented on a Personal Computer (PC); (2) that it calculates the cutbacks in civilian consumption necessary to meet military requirements; and (3) offers alternatives to fulfill supply requirements.

The model utilizes most of the data used for the REGRIP model except that, while REGRIP differentiates only between civilian consumption and military requirements, ROCS deals with more detailed categories of civilian consumption: (1) personal consumption expenditures; (2) investment; (3) exports; (4) non-military Federal government purchases; and (5) state and local government purchases. ROCS also differs from REGRIP in that an involved linear programming solution is not required. Another feature of ROCS is the inclusion of data on the sources of imports from 18 regions of the world; the user may supply their own estimates of import percentages and reliability for each region.

Estimating Employment Requirements and Availability

DoL is responsible for estimating and evaluating all aspects of the U.S. labor force for a military emergency. This includes estimating both defense and civilian labor requirements by specific industry and occupation, projecting the labor force available, and determining the feasibility of mobilization scenarios in terms of labor resources.

The Economic Growth System (EGS) of the Bureau of Labor Statistics (BLS) is designed to project the military and civilian labor force by age and sex, labor productivity and labor requirements for 378 industries and 550 occupations. This system is used to estimate labor requirements that are consistent with macroeconomic assumptions and conditions and industry production levels estimated by DoC. The EGS model overlaps the macroeconomic models used to predict the economy and production estimates made by DoC. Its uniqueness in the interagency framework is the employment and occupations matrices incorporated into the EGS model.

The EGS contains the Labor Force Model which projects the labor force based on projections made by the Bureau of the Census of "total population including Armed Forces overseas." The population estimates are grouped by age, sex, and race. Labor force participation rates are projected by BLS for each of 54 demographic groups and applied to the population data to estimate the aggregate labor. This technique provides, in effect, an estimate of capacity in terms of labor resources against which to evaluate the demand for labor as determined from estimates of output by industry that will be required in the mobilization effort. Undoubtedly, in developing the scenario for the emergency, personnel requirements for the armed forces would have an impact on projection of the civilian labor forces and on projections of potential GNP when formulating the macroeconomic model. Similarly, the demographic detail of the population and labor force participation rates will give guidance in policy decisions dealing with the perceived labor shortages in the resource evaluation procedure.

The BLS Economic Growth System contains an input-output model that is used to convert estimates of the level of GNP and its components into estimates of gross output for 156 industries. The estimated industry outputs are used to project employment by industry using a Labor Demand Model. However, for consistency in the interagency program, the EGS can accept estimates of gross output by industry for the overall resource assessment system which would be in greater industry detail. When aggregated to the classification system consistent with the Labor Demand Model, gross output by industry can be converted into related employment by industry and then aggregated to assess total requirements for civilian employment.

The Economic Growth System also contains an Occupational Demand Model which uses industry occupational staffing patterns to estimate the skill requirements of industries for 550 occupations which, when aggregated, will yield estimates of total employment by occupation.

Estimating Infrastructure Requirements

DoE is the resource agency charged with energy resource management functions. In providing analytical capability in support of these functions, the Energy Information Administration maintains a complete hierarchy of models and modeling systems to evaluate alternative aspects of energy supply and demand to provide the basis for policy decisions within the DoE. This analytical capability can be called upon in support of an interagency resource assessment plan to examine the energy-related aspects of a military mobilization.

The Energy Disaggregated Input-Output (EDIO) model is an energy oriented input-output system designed to expand the Department's capability to analyze the potential industrial economic impacts of energy policies. In presenting a more systematic representation of the basic energy interrelationships in the economy, the EDIO model permits a much more detailed analysis of the energy requirements within an I-O framework.

The sectoring plan in EDIO is important since it defines the industry and commodity detail. While the industry classification used in EDIO can be related to the other I-O systems available for mobilization analysis, the basic focus of the EDIO table is energy, and therefore, the EDIO industry classification emphasizes energy products. The model disaggregates energy producing industries, industries consuming large amounts of energy per unit of output from other sectors of the economy, thus enabling the analyst to identify explicitly those industries most likely to be affected by energy policy. These features provide a model capable of identifying the sectoral economic impacts for different energy and macroeconomic scenarios. On the other hand, in other areas of the economy where energy is not particularly important, the industries have been combined to yield a smaller, more manageable system but one with considerably more energy detail.

There are two approaches that can be taken in utilizing the EDIO model in an interagency resource assessment system. The model itself is essentially self contained requiring as inputs components of gross national product from a macroeconomic model. This requirement would be satisfied in the general plan of the overall assessment system which employs such a model in developing the mobilization scenario. The EDIO system has a submodel which disaggregates the GNP components into their industrial composition in order to compile a vector of final demand in the industrial detail compatible with the EDIO models i.e., a bill-of-goods representing sales to users by each of the 117 sectors of the model. Total gross output by industry to satisfy a given bill-of-goods is derived through multiplication of the EDIO inverse matrix and the bill-of-goods.

Another approach to the assessment of energy requirements during the mobilization recognizes that a central and coordinating element to the resource assessment system is the step which estimates the gross output by industry required to support the mobilization effort. This calculation is carried out using an I-O model with much greater industrial detail (i.e., the 500-order industry/commodity tables produced at DoC by BEA). The industry detail of gross output from these estimates can be aggregated to the level of industrial detail consistent with that maintained at DoE. Energy output coefficients from the EDIO model or from the National Energy Accounts (NEA) system can then be applied to determine energy requirements.

In the end, this may be a more flexible approach since the energy inputs are perhaps some of the more variable inputs to industry and, within limits, alternative configurations of energy sources and allocations can be evaluated without significant feedback effects that would alter the output required of the rest of the producing industries.

TRANSPORTATION

DoT has developed and utilizes a demand/capacity model which translates a given level of the U.S. economy into an estimated demand on the domestic transportation sector.[1] This model has the capability to address both the overall mobilization-related transportation demand/capacity requirements and also the potential impact on the transportation infrastructure caused by physical denial and/or labor stoppages.

The input to operate the DoT model would be available generally from the resource assessment process. To estimate transportation requirements related to the production and use of commodities, the DoT model converts dollar measures of commodity output by industry into quantities transported. The estimates of industrial output required by an emergency is part of the overall resource assessment system and would be supplied in common to all participants in the exercise. A consideration in coordinating the transportation analysis would be the need to accommodate differing classification systems and price levels in the related models and to formulate the data on other than annual (e.g., a quarterly basis). These problems can be anticipated and should cause no difficulty in the planning process.

[1] In a recent training program for National Defense Executive Reservists, DoT employed DGEM as the macroeconomic driver for the Transportation Express Model.

The DoT transportation industry submodel apportions the industrial output of commodities, in tonnages, among the rail, truck, domestic water and domestic air modes in a way which is consistent with data on historical patterns of the distribution of commodity shipments among the modes. Then, with information on the average lengths of haul, it estimates the ton-mile demand by mode on the transportation system.

The surge requirements for commercial transportation resources to move defense personnel and material to initial deployment and resupply centers are estimated and supplied to DoT by DoD's Military Traffic Management Command in the form of tonnages and personnel to be transferred between designated origin and destination points in the continental U.S. and by mode of transportation.

The combination of the military and nonmilitary requirements form the estimates of the demand to be placed on the commercial transportation system during the emergency period. These demands are assessed by DoT in terms of their estimates of the capacity of the transportation system to handle the load and to determine limits to the level of freight services that can be attained realistically under both short term and extended emergency conditions. The emergency capacity concept assumes adequate supplies of supporting resources and is based on a realistic assessment of vehicle utilization. Thus, the current and projected inventory of heavy trucks is rated at recently achieved high average annual miles per vehicle and average annual payload tons to estimate the intercity ton mile capacity of the heavy truck fleet.

Similarly, the estimated rail freight ton-mile capacity is based on recent peak utilization factors and is the product of the standing weight capacity of the rail car fleet, the maximum average trips per car per year, the maximum practical load factor and average haul.

The model implies that the major component of transportation activity continues to be production and consumption in the civilian sector and that commodity distribution patterns and seasonality of demand for various vehicles categories will remain essentially unchanged, though possibly scaled in proportion to overall economic activity.

AGRICULTURE

In fulfilling its responsibility to assure high levels of performance by the food and fibre system of the United States, Agriculture has developed a comprehensive econometric model of the U.S. agricultural sector. The model has two main objectives. One is to enhance and support the agency's ability to provide economic intelligence and make forecasts for the intermediate term. The other is to provide a means to evaluate and quantify the impacts of alternative policies or legislative proposals on the agricultural sector. The model entitled Food and Agricultural Policy Simulator (FAPSIM) is designed to estimate simultaneously a price-quantity equilibrium solution for a set of livestock and crop products. It also determines farm production expenses, cash receipts, net farm income, government deficiency and reserve storage payments, consumer price indexes for food products and farmer participation in government commodity programs.

The FAPSIM model includes all the major livestock and crop commodities that would be significant for support of the population and the economy during a mobilization period. It is a more detailed and dynamic approach to simulating the agricultural sector than is contained in the standard input-output models and, therefore, would be a more flexible tool to use in dealing with mobilization or emergency situations. Its policy analysis capability enables it to deal explicitly with problems likely to arise in an emergency. However, the FAPSIM model requires the input of substantial information of a different character and detail than is usual in or derived from the other models in the resource assessment system. For instance, one major subcategory of exogenous variables are government policy variables such as individual crop loan rates, target prices, national program yields and acreages, and diversion and set aside rates. These are questions that need to be addressed and resolved in developing a scenario for the mobilization period. Another major subcategory of exogenous variables are the macroeconomic variables such as population, disposable personal income, food processing wage rates, petroleum prices, nonfood consumer price index, etc. These are the variables that generally form part of the macroeconomic model that will be used to describe and establish the size and shape of the economy in the emergency. In all, the FAPSIM model requires input of 265 exogenous variables many of these variables are of an economic nature. Consequently, the requirements for running FAPSIM must be considered in developing a scenario and the variables most likely to be affected in the emergency must be stipulated in a manner consistent with the model.[1]

INTERIOR

The use of critical and strategic materials by industry is an important concern in mobilization planning. In fact, a stockpile of these materials is maintaianed by the Federal government in anticipation that excessive quantities of these commodities will be required during an emergency. The quantities of these materials necessary to produce the military, basic industrial and essential civilian needs are based on estimates of material usage per unit of output of an industry, estimates of outputs by industries, and estimated supply availability of these products.

Interior's, Bureau of the Mines maintains sufficient worldwide supply data for the stockpiled materials. The Department of Commerce has estimated the material usage per unit of output by end-using industry from information from the Bureau of Mines, the Census of Manufacturers, and from the industry. Projections of material usage per unit of output by industry (materials consumption ratios) are made and substitution factors are introduced to estimate what the usage of material will be during the crisis. These ratios are applied to the emergency industry outputs and each material requirement is summed across all industries. Currently, there is no model maintained by either Interior or Commerce to do this analysis. In the past, FEMA has been responsible for the material estimates. However, this responsibility has recently been given to the Department of Defense and the models to be used have not been selected.

[1]Recently, the DoA acquired a copy of the DGEM source code to determine ways in which DGEM could generate estimated values of critical "economic variables" required by FAPSIM.

Conclusion

Sufficient analytical resources exist within the major administrative agencies to support planning for resources needed during a military mobilization. Further, this work can be provided for in an interactive, interagency setting that allows each of the agencies to estimate resources for which that agency is responsible during a military mobilization using the same set of assumptions and using the same economic and military scenarios. Macroeconomic models, such as DGEM, occupy a central position in this analytical framework. The potential benefits from the use of DGEM in this setting are due in part to its availability to all members as a non-proprietary software system and in part to its intended use as an emergency management model. In addtion, the use of DGEM may encourage greater consistency among the other models and provide an avenue for feedback within the overall analytical framework.

APPENDIX E: DICTIONARY OF TERMS USED IN DGEM

The purpose of this appendix is twofold. First, it is used to expand upon some of the information presented in Chapters 6 through 9. Second, it should facilitate any cross referencing between the endogenous variables, included in the ENDOG COMMON block, and the exogenous variables, included in the EXOG COMMON block, with the program summaries given in Appendix F.

E.1 ENDOGENOUS VARIABLES

The text which follows provides a brief description of each of DGEM's endogenous variables.

CC	Real consumption of goods and services.
CDI	Values of household purchases of capital goods.
CDIM	Value of services from household capital.
CDIMQ	Real services from household capital.
CDIQ	Real purchases of household capital.
CNIA	Personal consumption expenditures (uses NIPA definition).
CNIAP	Personal consumption expenditure price deflator, NIPA.
CNIAQ	Real personal consumption expenditure, NIPA.
CX(i)	Proportion of domestic supply in total real supply of good or service i.
D	Value of depreciation of private domestic capital.
DG	Value of government deficit (excluding social insurance funds).
DLDA(i)	Rate of change in overall factor productivity in producing sector i.
DR	Value of the rest of the world deficit with the U.S.
E	Value of government purchases of goods and services.
GD	Real private net claims on the government.
GNIA	Government purchases of goods and services, NIPA.
GNIAP	Government purchases of goods and services price deflator, NIPA.
GNIAQ	Real government purchases of goods and services, NIPA.
GNP	Gross national product, NIPA.

GNPP Gross national product price deflator, NIPA.

GNPQ Real gross national product, NIPA.

INIA Gross private domestic investment, NIPA.

INIAP Gross private domestic investment price deflator, NIPA.

INIAQ Real gross private domestic investment, NIPA.

IVT Real private domestic investment including purchases of household capital.

K Total real private domestic capital stock, end of year.

KD Total real private domestic capital services.

LB Quantity of labor services supplied by the household sector.

LH Household sector time endowment.

LP Quantity of time consumed as leisure by the household sector.

MNIA Imports, NIPA.

MNIAP Imports price deflator, NIPA.

MNIAQ Real imports, NIPA.

P(i,j) Price index for purchases of good or service i by sector j.

PCC Price index of consumption goods and services.

PCCXCC Value of household expenditure on consumption of goods and services.

PDOM(m) Price index for domestic oil and natural gas.

PFM(i) Scale factor for relative purchase prices of good or service i.

PFXF Value of household expenditure of consumption of goods, services and leisure.

PI Price of investment goods.

PK Price of private domestic capital stock.

PKD Price of capital services.

PKLG Price of capital stock using the previous year's weights in aggregation.

PLB	Net price of labor services received by households.
PLM	Scale factor for relative purchase prices of labor services.
PO(i)	Price, received by the producer, for domestic production of good or service i.
POP	Population over 16 years of age.
PZ(i)	Supply price of good or service i.
QE(k)	Quantity of delivered energy of fuel type k.
QED	Quantity of total delivered energy.
QEE	Quantity of electricity generated.
QEF	Quantity of energy input into electricity generation.
QEG(k)	Quantity of energy input of fuel type k into electricity generation.
QEH	Total U.S. primary energy input.
QEI(k)	Quantity of primary energy input of fuel type k.
RD	Real net claims by the U.S. on the rest of the world.
RK	Government revenue from taxes on capital income.
RL	Government revenue from taxes of labor income.
RNT	Rate of return on private domestic capital.
RNW	Rate of return on private wealth.
RP	Government revenue from taxes on property.
RW	Government revenue from taxes on wealth.
RX	Government revenue from sales and excise taxes, less subsidies.
S	Value of gross private saving.
V	Value of capital gains on private wealth.
W	Private national wealth.
XNIA	Exports, NIPA.
XNIPA	Exports price deflator, NIPA.

XNIAQ	Real exports, NIPA.
XT(i)	Total real output from sector i.
Y	Value of gross private national income.
YF(i)	Real final demand for good or service i.
ZT(i)	Total real demand for good or service i.
ZX(i,j)	Real transactions of good or service i into sector j.

E.2 EXOGENOUS VARIABLES

The text which follows provides a brief description of each of DGEM's exogenous variables.

CC72	Real consumption of goods and services, 1972.
CYQ	Aggregation variable between components and total real personal consumption expenditure.
EI	Net interest paid by the government to the private domestic sector.
EIR	Net interest paid by the government to rest of world.
EJ	Investment income paid by the government to social insurance funds.
EL	Government transfers, other than from social insurance funds, to persons.
ER	Government transfers to foreigners.
ET	Government net foreign investment.
GYQ	Aggregation variable between components and total real government pruchases.
GZ(1)	Federal defense purchases.
GZ(2)	Federal nondefense purchases.
GZ(3)	State and local government purchases.
HR	Personal transfer payments to foreigners.
IYQ	Aggregation variable between components and total gross private domestic investment.

LH Total time available to the household sector.

NRE Net reinvested earnings, rest of world.

PCC72 Price index of consumption goods and services, 1972.

PGD Price of private net claims on the government.

PLB Price, received by households, of labor services.

PMR Price of imported goods and services.

PRD Price of net claims on the rest of the world.

RE Current surplus of government enterprises.

RI Excise and sales tax accruals allocated to investment goods.

RLU Rate of civilian unemployment.

RM Aggregation variable between components and total government revenue.

RR Customs duties.

RT Personal non-tax payments to the government.

RV Transfers from social insurance funds to the government.

RZ Total real exports of goods and services.

SDR Allocation of special drawing rights.

T(i) Rate of Sales and excise tax, less subsidy, an output from sector i.

TIME Time or year index, 1972 = 0.

TK Rate of tax on capital income.

TLB Rate of tax on labor income.

TP Rate of tax on property value.

TT(i,j) Rate of excise tax on sales of i to j.

TV Rate of tax on income from net claims on the government and the rest of the world.

TW Rate of tax on the value of private wealth.

U — Rate of depreciation of capital.

VR — Net interest and corporate profits from the rest of the world.

VRQ — Real net interest and corporate profits from the rest of the world.

XYQ — Aggregation variable between components and total net exports.

APPENDIX F: DESCRIPTION OF SUBROUTINES

This appendix provides a brief description of all subroutines in the model. For the MAIN program, a more detailed description by functional block is given in Chapter 7. The appendix is arranged in alphabetical order by subroutine name. Each subroutine is described on a single program summary sheet. This summary sheet includes: (a) the name of the subroutine; (b) the call statement; (c) a narrative description; (d) the calling routines; (e) the called routines; (f) the COMMON blocks referenced; and (g) any modifications which were made to bring the code up to the ANSI X3.9-1978 standard for FORTRAN. The information provided on the summary sheets in conjunction with the model flowchart shown in Chapter 7 is designed to complement the DGEM documentation reports and to facilitate the task of effectively maintaining the model. The interactions among subroutines which are explicitly stated on the summary sheets should also assist programmers in making any modifications to the source code dictated by user needs or pecularities of the host operating system.

PROGRAM SUMMARY SHEET

Subroutine Name: ARLAB

Call Statement: ARLAB(ARRAY,NUMROW,NUMCOL,LABEL)

Description:

This subroutine produces as an output to a file or a line printer a label and the values contained in a single-precision, floating-point array.

Called By: NEWTMA,NEWTM,NEWTMB,AR3LAB,OUTMOD

Calls:

Commons Referenced:

Program Modifications:

Uses FORTRAN CHARACTER statements rather than word bytes.

PROGRAM SUMMARY SHEET

Subroutine Name: ARLIST

Call Statement: ARLIST(ARRAY,NUMROW,NUMCOL)

Description:

This subroutine produces as an output to a file or a line printer the values contained in a single-precision, floating-point array.

Called By: NEWTM

Calls:

Commons Referenced:

Program Modifications:

PROGRAM SUMMARY SHEET

Subroutine Name: AR3LAB

Call Statement: AR3LAB(ARRAY,INDEX1,INDEX2,INDEX3,NAME)

Description:

This subroutine constructs a subarray from a 3-dimensional array.

Called By: OUTMOD,AR4LAB

Calls: ARLAB

Commons Referenced:

Program Modifications:

Uses FORTRAN CHARACTER statements rather than word bytes.

PROGRAM SUMMARY SHEET

Subroutine Name: AR4LAB

Call Statement: AR4LAB(ARRAY,ITIER,ILEVEL,IROW,ICOL,NAME)

Description:

This subroutine constructs a subarray from a 4-dimensional array.

Called By: OUTMOD

Calls: AR3LAB

Commons Referenced:

Program Modifications:

Uses FORTRAN CHARACTER statements rather than word bytes.

PROGRAM SUMMARY SHEET

Subroutine Name: CHROPT

Call Statement: CHROPT

Description:

This routine places state values into the FLDTA array for special characters according to the character set; it also reads option information and sets the DEBUG flag accordingly.

Called By: MAIN

Calls:

Commons Referenced: CHRSET,OPTN

Program Modifications:

Replaces old OPTION routine. Initializes FLDTA in terms of host system FORTRAN character set rather than OCTAL field codes. Replaces part of the original parser routines.

PROGRAM SUMMARY SHEET

Subroutine Name: CNTRLR

Call Statement: CNTRLR

Description:

This subroutine reads the run control information. For example, the first and last years of the simulations, whether the simulation is static or dynamic and the numbers of target-instrument pairs, data changes and outputs. The names and values of the variables are also read.

Called By: MAIN

Calls: GETOUT

Commons Referenced: CNTRL,OPTN,OUTPTA,TARINF

Program Modifications:

Replaced non standard free-format read with a standard free-format read. Inserted OPEN statements. Replaced INCLUDE statements with COMMON and PARAMETER statements.

PROGRAM SUMMARY SHEET

Subroutine Name: CONVRT

Call Statement: CONVRT

Description:

This subroutine takes logs of lagged variables.

Called By: MAIN

Calls:

Commons Referenced: CNTRL,COEFF,ENDOG,EXOG,LAG,
OPTN,TARINF

Program Modifications:

Replaced INCLUDE statements with COMMON and PARAMETER statements.

PROGRAM SUMMARY SHEET

Subroutine Name: CONVT72

Call Statement: CONVT72

Description:

Converts government purchases and exports to 1972 dollars.

Called By: MAIN

Calls:

Commons Referenced: CNTRL,COEFF,ENDOG,EXOG,LAG,
OPTN,TARINF

Program Modifications:

New routine.

PROGRAM SUMMARY SHEET

Subroutine Name: CONVT82

Call Statement: CONVT82

Description:

Converts government purchases and exports to 1982 dollars.

Called By: MAIN

Calls:

Commons Referenced: CNTRL,COEFF,ENDOG,EXOG,LAG,
OPTN,TARINF

Program Modifications:

New routine.

PROGRAM SUMMARY SHEET

Subroutine Name: DATA

Call Statement: DATA(JYEAR,LAG)

Description:

This subroutine reads data for a given year. LAG is one if retrieving last year's data; zero otherwise.

Called By: MAIN

Calls:

Commons Referenced: CNTRL,COEFF,ENDOG,EXOG,OTPTNM, OUTPTA,TARINF

Program Modifications:

Replaced INLUCDE statements with COMMON and PARAMETER statements. File read on unit 8 is now defined and opened within the MAIN program.

PROGRAM SUMMARY SHEET

Subroutine Name: DECSOL

Call Statement: DECSOL(N,A,F,X,NDIM)

Description:

This subroutine solves a linear system using Gaussian elimination with partial pivoting, followed by back substitution. It is used in the Newton's method procedures and also to solve the linear system of interindustry transaction balances.

Called By: NEWTM,FCRVAL,NEWTMA

Calls: SINGE

Commons Referenced:

Program Modifications:

No longer includes subroutine SINGE. Replaced INCLUDE statement with PARAMETER statement.

PROGRAM SUMMARY SHEET

Subroutine Name: ENERGY

Call Statement: ENERGY

Description:

This subroutine calculates the aggregate energy consumption figures for each fuel and in total for a given year.

Called By: FCRVAL

Calls:

Commons Referenced: COEFF,ENDOG,EXOG

Program Modifications:

Replaced INCLUDE statements with COMMON and PARAMETER statements.

PROGRAM SUMMARY SHEET

Subroutine Name: ERR

Call Statement: ERR(CODE,IVAR,INREC)

Description:

Prints an error message according to a table of error codes for an incorrect target-instrument combination.

Called By: PARSE,NUMBRS,OFFSET,PACK,SEARCH

Calls:

Commons Referenced:

Program Modifications:

No longer included within the GETOUT routine. Calling sequence made explicit. Uses FORTRAN CHARACTER statement rather than word bytes.

PROGRAM SUMMARY SHEET

Subroutine Name: FCR

Call Statement: FCR(XN,RESID,N)

Description:

This subroutine evaluates the residuals corresponding to the 40 variables in the basis. The first residual corresponds to the variable IVT, the next 36 residuals correspond to the vector PFM(i), the next residuals are for PKD, PLM and RNW, respectively. In addition, each equality constraint imposed on the model introduces a new equation; these equations are included in the block of residuals. The variable corresponding to each of these equations is the instrument nominated by the user.

Called By: NEWTM

Calls: FCRVAL

Commons Referenced: CNTRL,COEFF,ENDOG,EXOG,LAG,OPTN, TARINF,TIERH,TIERP

Program Modifications:

Replaced INCLUDE statements with COMMON and PARAMETER statements.

PROGRAM SUMMARY SHEET

Subroutine Name: FCRA

Call Statement: FCRA(RES)

Description:

Upon receiving values for the output prices, PO(i), from NEWTMA, FCRA evaluates the KLEM shares (capital, labor, energy, material) and price residuals implied by the price frontiers.

Called By: NEWTMA

Calls: SHPRA

Commons Referenced: CNTRL,COEFF,ENDOG,EXOG,ICOB,LAG,OPTN, TIERH,TIERP

Program Modifications:

No longer included within the NEWTMA routine. Replaced INCLUDE statements with COMMON and PARAMETER statements.

PROGRAM SUMMARY SHEET

Subroutine Name: FCRB

Call Statement: FCRB(RES)

Description:

This subroutine calculates residuals for the household submodel.

Called By: NEWTMB

Calls: SHPRB

Commons Referenced: CNTRL,COEFF,ENDOG,EXOG,LAG,OPTN, TIERH,TIERP

Program Modifications:

No longer included within the NEWTMB routine. Replaced INCLUDE statements with COMMON and PARAMETER statements.

PROGRAM SUMMARY SHEET

Subroutine Name: FCRVAL

Call Statement: FCRVAL

Description:

Forms primary input prices and estimates of output prices. This subroutine contains most of the equations of the model. The output prices are calculated numerically by a Newton's method procedure in NEWTMA. Consumption patterns are calculated numerically by NEWTMB.

Called By: FCR,NEWTMA

Calls: DECSOL,ENERGY,NEWTMA,NEWTMB,NIPABR

Commons Referenced: CNTRL,COEFF,ENDOG,EXOG,LAG,OPTN,
TARINF,TIERH,TIERP

Program Modifications:

Replaced INCLUDE statements with COMMON and PARAMETER statements.

PROGRAM SUMMARY SHEET

Subroutine Name: GETOUT

Call Statement: GETOUT(NUMVAR,LOCVAR,KEYVAR,SAVNAM,STRTNM,
NAMFIN,NMFLAG)

Description:

Parses target inputs and calculates pointers to the endogenous and exogenous variable common blocks.

Called By: CNTRLR

Calls: OFFSET,PARSE,SEARCH

Commons Referenced: B,CHRSET,DIMSIZ,OPTN

Program Modifications:

No longer includes Subroutines: ERR; PARSE; PACK; OFFSET; NUMBRS; and SEARCH. Uses FORTRAN CHARACTER statements rather than word bytes. Changes in COMMON blocks and initialization for parsing variable names and subscripts.

PROGRAM SUMMARY SHEET

Subroutine Name: GUESS

Call Statement: GUESS(XN,NVAR)

Description:

This subroutine reads the base case values of the endogenous variables (the ENDOG COMMON block) and extracts the values of the basis variables used in the numerical solution of the model. When targets are being enforced, the actual values of the nominated instruments are also extracted. These values are inserted into the vector XN and serve as the initial guesses of the variables in the numerical solution of the model.

Called By: MAIN

Calls:

Commons Referenced: COEFF,ENDOG,EXOG,OPTN,TARINF

Program Modifications:

Replaced INCLUDE statements with COMMON and PARAMETER statements.

PROGRAM SUMMARY SHEET

Subroutine Name: NEWTM

Call Statement: NEWTM(X,N,*)

Description:

This subroutine contains a first order Newton's method algorithm for the solution of an equation system; it solves for values of the N basis variables. Equilibrium is reached when all N residuals are simultaneously zero.

Called By: MAIN

Calls: ARLAB,ARLIST,DECSOL,FCR,FCRVAL,OUTMOD

Commons Referenced: CNTRL,COEFF,ENDOG,EXOG,LAG,OPTN,TARINF

Program Modifications:

Replaced INCLUDE statements with COMMON and PARAMETER statements. Changed value of test variable, CONV, for the sum squared of the residuals.

PROGRAM SUMMARY SHEET

Subroutine Name: NEWTMA

Call Statement: NEWTMA

Description:

This subroutine is a simplified Newton's method algorithm for the solution of a system of equations. It is set up specifically for the solution of the price possibility frontiers for the values of the sectoral output prices, PO(i). The model equations used in this solution are in subroutines FCRA and SHPRA.

Called By: FCRVAL

Calls: ARLAB,DECSOL,FCRA

Commons Referenced: CNTRL,COEFF,ENDOG,EXOG,LAG,OPTN,
TIERH,TIERP

Program Modifications:

No longer includes subroutines FCRA and SHPRA. Replaced INCLUDE statements with COMMON and PARAMETER statements. Changed value on test variable, CONVY, for the sum squared of the residuals.

PROGRAM SUMMARY SHEET

Subroutine Name: NEWTMB

Call Statement: NEWTMB

Description:

This is a simplified Newton's method algorithm used to solve for the expenditure weighted consumption price PCC. The equations corresponding to these prices are in subroutines FCRB and SHPRB.

Called By: FCRVAL

Calls: ARLAB, FCRB

Commons Referenced: CNTRL, COEFF, ENDOG, EXOG, LAG, OPTN, TIERH, TIERP

Program Modifications:

No longer includes subroutines FCRB and SHPRB. Replaced INCLUDE statements with COMMON and PARAMETER statements. Changed value on test variable, CONVY, for the sum squared of the residuals.

PROGRAM SUMMARY SHEET

Subroutine Name: NIPABR

Call Statement: NIPABR

Description:

This subroutine calculates the values of the components of the National Income and Product Accounts (GNP, consumption, investment, government, exports, imports). These aggregates are constructed from the solved values of the endogenous variables and the exogenous conditions that determine them.

Called By: FCRVAL

Calls:

Commons Referenced: COEFF,ENDOG,EXOG,LAG

Program Modifications:

Changed initialization procedure for aggregation of GNP components.

PROGRAM SUMMARY SHEET

Subroutine Name: NUMBRS

Call Statement: NUMBRS(RESULT,NUMCHR,IVAR,ITRING,INREC)

Description:

Packs 3 digits from vector ITRING into RESULT.

Called By: PARSE

Calls: ERR

Commons Referenced:

Program Modifications:

No longer included within GETOUT routine. Uses FORTRAN CHARACTER statements rather than word bytes.

PROGRAM SUMMARY SHEET

Subroutine Name: OFFSET

Call Statement: OFFSET(IVAR,SUB1,SUB2,SUB3,SUB4,POINT,INREC,
KEYVAR,LOCVAR)

Description:

Calculates the location of a variable in a COMMON block.

Called By: GETOUT

Calls: ERR

Commons Referenced: DIMSIZ,OPTN

Program Modifications:

No longer included within the GETOUT routine.

PROGRAM SUMMARY SHEET

Subroutine Name: OUTBTU

Call Statement: OUTBTU(JYEAR)

Description:

This subroutine prints out the national energy transactions in quadrillion BTU.

Called By: MAIN

Calls:

Commons Referenced: COEFF,ENDOG

Program Modifications:

Replaced INCLUDE statements with COMMON and PARAMETER statements. Uses FORTRAN CHARACTER statements rather than word bytes.

PROGRAM SUMMARY SHEET

Subroutine Name: OUTMOD

Call Statement: OUTMOD(JYEAR)

Description:

This subroutine prints out the values of the endogenous variables, exogenous variables and coefficients.

Called By: MAIN,NEWTM

Calls: ARLAB,AR3LAB,AR4LAB

Commons Referenced: B,COEFF,ENDOG,EXOG,LAG,OPTN,TARINF

Program Modifications:

Replaced INCLUDE statements with COMMON and PARAMETER statements. Uses FORTRAN CHARACTER statements rather than word bytes. Modified CALL statement for subroutines, ARLAB, AR3LAB and AR4LAB.

PROGRAM SUMMARY SHEET

Subroutine Name: OUTNIA

Call Statement: OUTNIA(JYEAR)

Description:

This subroutine prints out the National Income and Produce Accounts for a given year.

Called By: MAIN

Calls:

Commons Referenced: ENDOG,EXOG,OPTN

Program Modifications:

Replaced INCLUDE statements with COMMON and PARAMETER statements. Uses FORTRAN CHARACTER statements rather than word bytes.

PROGRAM SUMMARY SHEET

Subroutine Name: OUTPUT

Call Statement: OUTPUT(YEAR1,YEAR2)

Description:

This subroutine prints an output report for each variable requested by the user. The simulated values are compared to the basecase values in each report.

Called By: MAIN

Calls:

Commons Referenced: OPTN,OTPTNM,OUTPTA,OUTPTB

Program Modifications:

Replaced INCLUDE statements with COMMON and PARAMETER statements. No longer includes functions DIVCHK and CHK. Conditional OPEN statement for storing simulated values of special variables.

PROGRAM SUMMARY SHEET

Subroutine Name: PACK

Call Statement: PACK(NAME,STRING,INREC,NUMCHR,IVAR)

Description:

Packs 6 characters from the vector STRING into NAME.

Called By: PARSE

Calls: ERR

Commons Referenced:

Program Modifications:

No longer included within the GETOUT routine. Uses FORTRAN CHARACTER statements rather than word bytes.

PROGRAM SUMMARY SHEET

Subroutine Name: PARSE

Call Statement: PARSE(ITHRU,IVAR,INREC,IICHAR,NMFLAG,SAVNAM,NAMFIN,STRTNM,STRING,ITRING,SUB1,SUB2,SUB3,SUB4,NAME,NUMCHR)

Description:

Parses card image into variable name and subscripts if appropriate. This subroutine expects variable names to be valid FORTRAN variable names. Presence of parentheses implies one, two, or three subscripts, separated by a comma.

Called By: GETOUT

Calls: ERR,NUMBRS,PACK

Commons Referenced: CHRSET,OPTN

Program Modifications:

No longer included within the GETOUT routine. This is the main routine where FORTRAN CHARACTER statements replaced word bytes.

PROGRAM SUMMARY SHEET

Subroutine Name: SAVLAG

Call Statement: SAVLAG

Description:

This subroutine extracts the variables that need to be saved for the next year's simulation. The first year's variables enter through the ENDOG, EXOG, and COEFF COMMON blocks; those variables needed for the next year's simulation are stored in the LAG COMMON block.

Called By: MAIN

Calls:

Commons Referenced: COEFF,ENDOG,EXOG,LAG

Program Modifications:

Replaced INCLUDE statements with COMMON and PARAMETER statements.

PROGRAM SUMMARY SHEET

Subroutine Name: SAVOUT

Call Statement: SAVOUT(ITIME,IFLAG)

Description:

This subroutine saves the values for each variable for which an output report was requested by the user. These values are used for comparison and for calculating rates of change.

Called By: MAIN

Calls:

Commons Referenced: CNTRL,COEFF,ENDOG,EXOG,OPTN,OTPTNM, OUTPTA,OUTPTB

Program Modifications:

Replaced INCLUDE statements with COMMON and PARAMETER statements.

PROGRAM SUMMARY SHEET

Subroutine Name: SEARCH

Call Statement: SEARCH(NAME,INREC,IVAR,KEYVAR,POINT)

Description:

Finds pointers to variable names in the list of variable names.

Called By: GETOUT

Calls: ERR

Commons Referenced: B

Program Modifications:

No longer included within the GETOUT routine. Uses FORTRAN CHARACTER statements rather than word bytes.

PROGRAM SUMMARY SHEET

Subroutine Name: SETDAT

Call Statement: SETDAT(JYEAR)

Description:

This subroutine writes data for a given year to a new file; it is activated by the M option. Since it causes a new database to be created, the M option should be used with caution.

Called By: MAIN

Calls:

Commons Referenced: CNTRL,COEFF,ENDOG,EXOG

Program Modifications:

Replaced INCLUDE statements with COMMON and PARAMETER statements. File written on unit 3 is now defined and opened within the MAIN program.

PROGRAM SUMMARY SHEET

Subroutine Name: SHPRA

Call Statement: SHPRA(INDEX,JS,ICD)

Description:

This subroutine calculates the energy and materials shares and the corresponding price aggregates.

Called By: FCRA

Calls:

Commons Referenced: CNTRL,COEFF,ENDOG,EXOG,ICOB,LAG,OPTN, TIERH,TIERP

Program Modifications:

No longer included within the NEWTMA routine. Replaced INCLUDE statements with COMMON and PARAMETER statements.

PROGRAM SUMMARY SHEET

Subroutine Name: SHPRB

Call Statement: SHPRB(INDEX)

Description:

Determines consumption expenditure patterns.

Called By: FCRB

Calls:

Commons Referenced: CNTRL,COEFF,ENDOG,EXOG,LAG,OPTN,
TIERH,TIERP

Program Modifications:

No longer included within the NEWTMB routine. Replaced INCLUDE statements with COMMON and PARAMETER statements.

PROGRAM SUMMARY SHEET

Subroutine Name: SINGE

Call Statement: SINGE(LOOP)

Description:

This subroutine prints the message that a singularity was encountered in DECSOL for a given loop number.

Called By: DECSOL

Calls:

Commons Referenced:

Program Modifications:

No longer included in the DECSOL routine.

PROGRAM SUMMARY SHEET

Subroutine Name: VARY

Call Statement: VARY

Description:

Determines the value for any endogenous or exogenous variable or coefficient which is being scaled or preset by the user.

Called By: MAIN

Calls:

Commons Referenced: CNTRL,COEFF,ENDOG,EXOG,OPTN,TARINF

Program Modifications:

Replaced INCLUDE statements with COMMON and PARAMETER statements.

FEDERAL INFORMATION PROCESSING STANDARD SOFTWARE SUMMARY

01. Summary date (Yr. Mo. Day)	89 01 06
02. Summary prepared by (*Name and Phone*)	Robert E. Chapman (301)975-2723
03. Summary action	New [X] Replacement [ ] Deletion [ ]
Previous Internal Software ID	
04. Software date (Yr. Mo. Day)	89 01 06
05. Software title	Dynamic General Equilibrium Model (DGEM)
06. Short title	
07. Internal Software ID	
08. Software type	Automated Data System [ ]; Computer Program [X]; Subroutine/Module [ ]
09. Processing mode	Interactive [ ]; Batch [ ]; Combination [X]
10. Application area — General	Computer Systems Support/Utility [ ]; Scientific/Engineering [X]; Bibliographic/Textual [ ]; Management/Business [X]; Process Control [ ]; Other [ ]
10. Application area — Specific	Macroeconomic Modeling
11. Submitting organization and address	Center for Computing and Applied Mathematics National Institute of Standards & Technology Gaithersburg, MD 20899
12. Technical contact(s) and phone	Robert E. Chapman (301)975-2723

13. Narrative

DGEM is an annual model for analyzing the structure and growth of the U.S. economy. DGEM provides a detailed analysis of supply and demand factors for simulations up through the year 2000. The model was designed to deal with three major types of emergency situations: (1) energy-economic interactions associated with supply interruptions or strategic policies; (2) the economic impacts of a loss of resources due to an enemy attack on the United States with particular emphasis on which policies could stimulate recovery; and (3) the economic impacts of demand surges and resource constraints typical during a period of military mobilization.

14. Keywords

economic analysis; emergency management; mathematical model; policy analysis

15. Computer manuf'r and model	16. Computer operating system	17. Programing language(s)	18. Number of source program statements
DEC VAX 11-780 series	VMS	FORTRAN 77	APPX 10000
19. Computer memory requirements	**20. Tape drives**	**21. Disk/Drum units**	**22. Terminals**
1 M Byte	9 track 1600 or 6250 FPI		

23. Other operational requirements

24. Software availability			25. Documentation availability		
Available [ ]	Limited [X]	In-house only [ ]	Available [X]	Inadequate [ ]	In-house only [ ]

26. FOR SUBMITTING ORGANIZATION USE

185-101

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Evaluating Emergency Management Models and Data Bases: A Suggested Approach

5. AUTHOR(S)

Robert E. Chapman, Saul I. Gass, James J. Filliben and Carl M. Harris

6. PERFORMING ORGANIZATION (If joint or other than NBS, see instructions)

NATIONAL BUREAU OF STANDARDS
U.S. DEPARTMENT OF COMMERCE
GAITHERSBURG, MD 20899

7. Contract/Grant No.

8. Type of Report & Period Covered

9. SPONSORING ORGANIZATION NAME AND COMPLETE ADDRESS (Street, City, State, ZIP)

Federal Emergency Management Agency
500 C Street, SW
Washington, DC 20472

10. SUPPLEMENTARY NOTES

☐ Document describes a computer program; SF-185, FIPS Software Summary, is attached.

11. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here)

The evaluation of large-scale mathematical models requires a set of analytical techniques which focus on quantitative rather than qualitative issues. The four major classes of analytical techniques described in this document are based on a thorough review of the technical literature in model and data base evaluation, practical experience, and original research on model information development. The analytical techniques discussed in this document include: (1) the theoretical considerations upon which a data base or the model's formulation rests; (2) program documentation and verification; (3) data base audits; and (4) the technical considerations associated with an in-depth sensitivity analysis. The individual techniques are designed in such a manner that they generate a framework of structural information and analysis which supports an in-depth model/data base evaluation.

12. KEY WORDS (Six to twelve entries; alphabetical order; capitalize only proper names; and separate key words by semicolons)

Assessment; data base; data quality; documentation; emergency planning; evaluation; mathematical model; model credibility; policy models; sensitivity analysis

13. AVAILABILITY

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